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EVALUATION OF IR COUNTERMEASURES CH-47 (CHINOOK) MODEL REPORT.(U)
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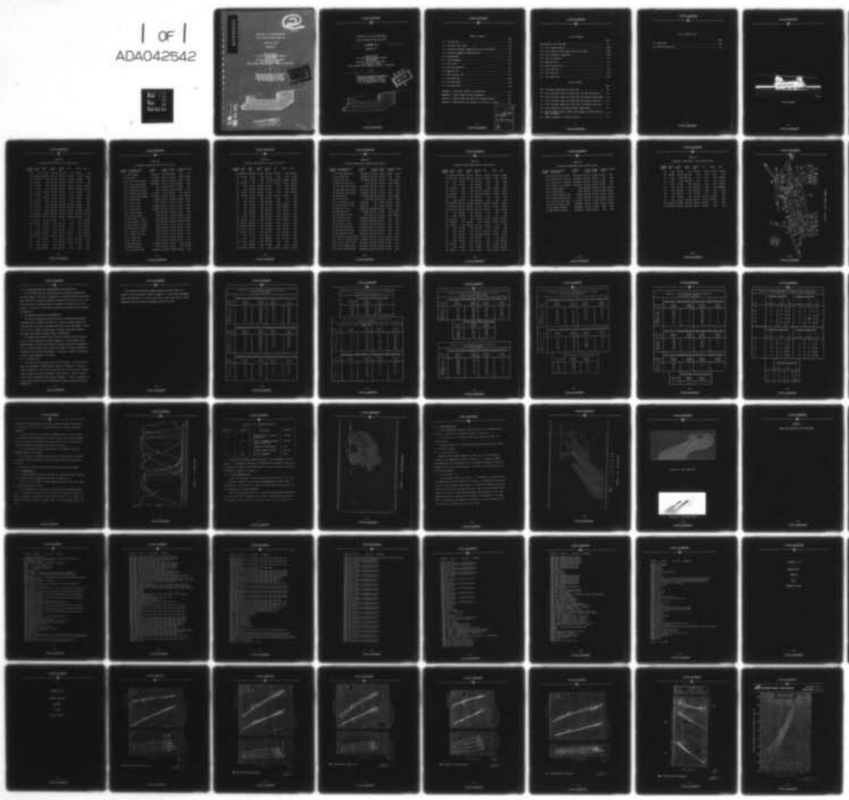

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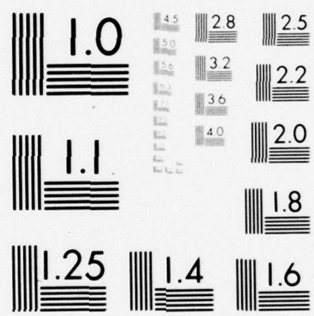

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Evaluation of IR Countermeasures

CH-47 (Chinook) Model Report (U)

October 16, 1973

Prepared for

Program Manager
U.S. Army Aviation Systems Command
AMCPM-AEWSPS
Box 209, 12th and Spruce Street
St. Louis, Mo. 63166
Under Contract DAAJ01-72-C-0447, Exhibit A, Data A003

by

Westinghouse Electric Corporation
Systems Development Division
Strike Systems Avionics, M/S-434
Box 746, Baltimore, Md. 21203

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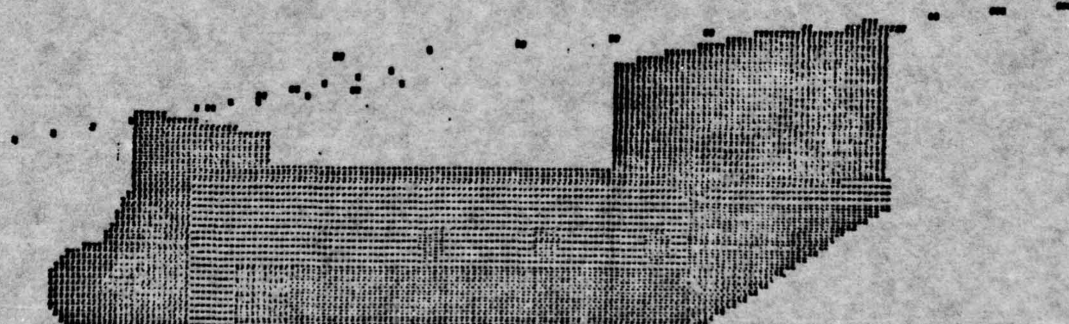

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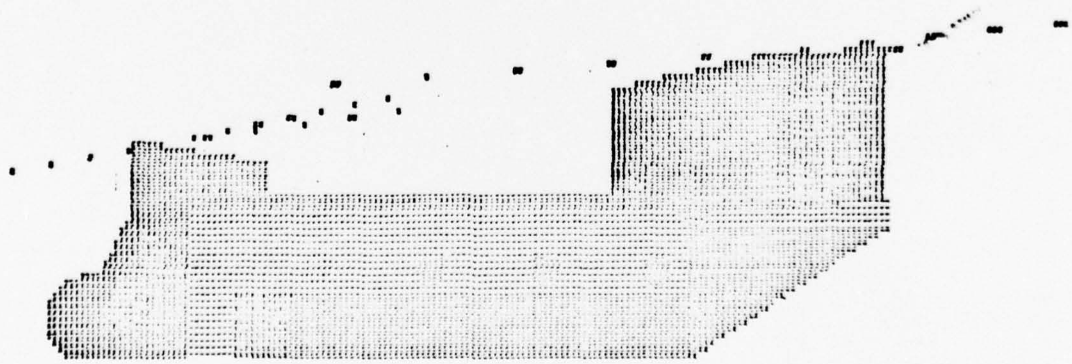

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RHD-8

CH-47 (Chinook)

1.0 (U) INTRODUCTION

The HIDE model is a comprehensive computer program designed to simulate the infrared signatures of Army aircraft.

The HIDE model was developed under contract DAA-J01-72-C-0447, "Evaluation of IR Countermeasures", for the U.S. Army Aviation Systems Command, AMCPM-AEWSPS. This work has been reported in two volumes:

Interim Technical Report (Model Methodology) 6-26-72

Final Technical Report (Phase II HIDE Model) 2-28-73

The original work developed the signature of a UH-1H helicopter. The work reported here is an extention to this contract to model a CH-47 helicopter to run in the HIDE model.

Section 2 defines the structural modeling referred to as body data.

Section 3 describes the turbine and air frame operational models.

Section 4 presents a predicted signature after integration into the HIDE model.

Appendices are included which contain program elements and reference data.

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2.0 (U) HELICOPTER BODY DATA

The CH-47 body was dissected into one hundred and twelve (112) surfaces as shown in Table 2-1. The technique used was that described in Appendix A of the Phase II Final Report.[1] A breakdown of the helicopter by surface types shows:

<u>78 flats including</u>:

25 rectangles (type 1),

24 discs (type 2),

29 trapesoids (type 3), and

<u>34 conics including</u>:

20 cylinders (type 4),

8 cones (type 5),

6 spheres (type 6), and

0 circular parabolids (type 7).

An isometric drawing of the helicopter showing how the helicopter was dissected is presented in figure 2-1. A numbered baloon for each surface indicates surface number and type. Dashed baloons are used for surfaces on the right side of the helicopter which are mirror images of left side surfaces. In each case, the surface number for the right side surface is one higher than the surface number for the mirror image surface on the left side.

A large computer printout showing the helicopter at a 70° aspect angle off the nose is shown in figure 2-2.

The numbers on the helicopter represent the surface number. Certain areas such as the windows, engines, and rotors are outlined for clarity. In figure 2-3, the front, top and side views from a computer

[1] Evaluation of Countermeasures, Phase II Hide Model Final Technical Report by Westinghouse Electric Corporation, February 28, 1972 (Secret)

Table 2-1

Helicopter Geometrical Structure Data

SURFACE NUMBER	HELICOPTER PART DESCRIPTION	SURFACE TYPE	FLIGHT STATION	WATER-LINE	BULKHEAD LINE	ALPHA
1	L.SIDE FUSELAGE	RECTANGLE	-125.000	.000	.000	54.000
2	R.SIDE FUSELAGE	RECTANGLE	-125.000	.000	.000	54.000
3	TOP FUSELAGE	RECTANGLE	-125.000	.000	.000	54.000
4	BOTTOM FUSELAGE	RECTANGLE	-200.000	.000	.000	40.000
5	L. TOP CURVED FUSELAGE	CYLINDER	-125.000	40.000	40.000	14.000
6	R. TOP CURVED FUSELAGE	CYLINDER	-125.000	40.000	-40.000	14.000
7	1ST L. FUSELAGE WINDOW	DISC	-140.000	15.000	.000	54.010
8	1ST R. FUSELAGE WINDOW	DISC	-140.000	15.000	.000	54.010
9	2ND L. FUSELAGE WINDOW	DISC	-220.000	15.000	.000	54.010
10	2ND R. FUSELAGE WINDOW	DISC	-220.000	15.000	.000	54.010
11	3RD L. FUSELAGE WINDOW	DISC	-300.000	15.000	.000	54.010
12	3RD R. FUSELAGE WINDOW	DISC	-300.000	15.000	.000	54.010
13	4TH L. FUSELAGE WINDOW	DISC	-380.000	15.000	.000	54.010
14	4TH R. FUSELAGE WINDOW	DISC	-380.000	15.000	.000	54.010
15	5TH L. FUSELAGE WINDOW	DISC	-460.000	15.000	.000	54.010
16	5TH R. FUSELAGE WINDOW	DISC	-460.000	15.000	.000	54.010
17	L. FUSELAGE CELL TOP	RECTANGLE	-200.000	-30.000	71.320	.000
18	R. FUSELAGE CELL TOP	RECTANGLE	-200.000	-30.000	-71.320	.000
19	L. FUSELAGE CELL	CYLINDER	-200.000	-40.000	54.000	20.000
20	R. FUSELAGE CELL	CYLINDER	-200.000	-40.000	-54.000	20.000
21	L. AFT SIDE FUSELAGE	TRAPESOID	-630.500	40.000	.000	54.000
22	R. AFT SIDE FUSELAGE	TRAPESOID	-630.500	40.000	.000	54.000
23	REAR FUSELAGE	RECTANGLE	-630.500	40.000	.000	.000
24	TOP REAR FUSELAGE	RECTANGLE	-630.500	40.000	.000	.000
25	L. TOP REAR FUSELAGE	DISC	-630.500	40.000	40.000	.000

Table 2-1

Helicopter Geometrical Structure Data (Cont.)

SURFACE NUMBER	BETA-MIN	BETA-MAX	GAMMA-MIN	GAMMA-MAX	PSI	THETA	PHI
1	-40.000	40.000	-357.000	.000	.000	.000	-90.000
2	-40.000	40.000	-357.000	.000	.000	.000	90.000
3	-40.000	40.000	-505.500	.000	.000	.000	.000
4	-74.000	74.000	-282.000	.000	.000	.000	180.000
5	.000	505.500	.001	90.000	.000	-90.000	.000
6	.000	505.500	90.000	180.000	.000	-90.000	.000
7	.000	10.000	.001	360.000	.000	.000	-90.000
8	.000	10.000	.001	360.000	.000	.000	90.000
9	.000	10.000	.001	360.000	.000	.000	-90.000
10	.000	10.000	.001	360.000	.000	.000	90.000
11	.000	10.000	.001	360.000	.000	.000	-90.000
12	.000	10.000	.001	360.000	.000	.000	90.000
13	.000	10.000	.001	360.000	.000	.000	-90.000
14	.000	10.000	.001	360.000	.000	.000	90.000
15	.000	10.000	.001	360.000	.000	.000	-90.000
16	.000	10.000	.001	360.000	.000	.000	90.000
17	-34.640	.000	-282.000	.000	.000	.000	-60.000
18	.000	34.640	-282.000	.000	.000	.000	60.000
19	.000	282.000	.001	90.000	.000	-90.000	.000
20	.000	282.000	90.000	180.000	.000	-90.000	.000
21	-148.500	.000	151.700	180.000	90.000	90.000	.000
22	-148.500	.000	180.000	208.300	90.000	-90.000	.000
23	-54.000	54.000	.000	83.400	.000	28.300	.000
24	-40.000	40.000	.000	14.000	.000	-90.000	.000
25	.000	14.000	.001	90.000	.000	-90.000	.000

Table 2-1

Helicopter Geometrical Structure Data (Cont.)

SURFACE NUMBER	HELICOPTER PART DESCRIPTION	SURFACE TYPE	FLIGHT STATION	WATER-LINE	BULKHEAD LINE	ALPHA
26	R. TOP REAR FUSELAGE	DISC	-630.500	40.000	-40.000	.000
27	LOWER REAR FUSELAGE	TRAPESOID	-756.500	108.000	.000	.000
28	L. AFT CELL TOP	TRAPESOID	-556.250	.000	54.000	.000
29	R. AFT CELL TOP	TRAPESOID	-556.250	.000	-54.000	.000
30	L. AFT CELL	TRAPESOID	-556.250	.000	54.000	.000
31	R. AFT CELL	TRAPESOID	-556.250	.000	-54.000	.000
32	L. AFT CELL INT. PL.	TRAPESOID	-482.000	.000	54.000	.000
33	R. AFT CELL INT. PL.	TRAPESOID	-482.000	.000	-54.000	.000
34	L. FWD CELL INT. PL.	TRAPESOID	-200.000	.000	54.000	.000
35	R. FWD CELL INT. PL.	TRAPESOID	-200.000	.000	-54.000	.000
36	L. FWD CELL TOP	TRAPESOID	-160.000	.000	54.000	.000
37	R. FWD CELL TOP	TRAPESOID	-160.000	.000	-54.000	.000
38	L. FWD CELL	TRAPESOID	-206.300	-40.000	77.150	.000
39	R. FWD CELL	TRAPESOID	-206.300	-40.000	-77.150	.000
40	MID BOTTOM FUSELAGE	TRAPESOID	-52.000	-40.000	.000	.000
41	MID FWD BOTTOM FUSELAGE	RECTANGLE	-125.000	-40.000	.000	.000
42	NOSE	CYLINDER	-46.500	-15.000	.000	25.000
43	L. SIDE NOSE	DISC	-46.500	-15.000	35.000	.000
44	R. SIDE NOSE	DISC	-46.500	-15.000	-35.000	.000
45	L. FWD SIDE	TRAPESOID	-125.000	96.000	54.000	.000
46	R. FWD SIDE	TRAPESOID	-125.000	96.000	-54.000	.000
47	L. FRONT WINDOW	CYLINDER	-46.500	-40.000	21.000	14.000
48	R. FRONT WINDOW	CYLINDER	-46.500	-40.000	-21.000	14.000
49	L. UPPER CORNER WINDOW	SPHERE	-92.700	40.000	32.190	14.000
50	R. UPPER CORNER WINDOW	SPHERE	-92.700	40.000	-32.190	14.000

Table 2-1

Helicopter Geometrical Structure Data (Cont.)

SURFACE NUMBER	BETA-MIN	BETA-MAX	GAMMA-MIN	GAMMA-MAX	PSI	THETA	PHI
26	.000	14.000	90.000	180.000	.000	-90.000	.000
27	-308.330	-224.930	166.500	193.500	90.000	.000	28.300
28	-74.250	.000	151.700	180.000	90.000	60.000	.000
29	-74.250	.000	180.000	208.300	90.000	-60.000	.000
30	-77.000	.000	152.530	155.750	90.000	90.000	-15.090
31	-77.000	.000	204.250	207.470	90.000	-90.000	-15.090
32	.000	20.000	60.000	63.420	.000	90.000	.000
33	-20.000	.000	116.580	120.000	.000	90.000	.000
34	.000	20.000	60.000	63.420	.000	90.000	.000
35	-20.000	.000	116.580	120.000	.000	90.000	.000
36	-40.000	.000	180.000	225.000	-90.000	-60.000	.000
37	-40.000	.000	135.000	180.000	-90.000	60.000	.000
38	-51.760	-7.060	180.000	217.750	90.000	90.000	26.550
39	-51.760	-7.060	142.250	180.000	90.000	-90.000	26.550
40	-148.000	-108.000	153.500	206.500	-90.000	180.000	.000
41	-54.000	54.000	-35.000	.000	.000	.000	180.000
42	-35.000	35.000	.001	360.000	.000	.000	90.000
43	.000	25.000	.001	360.000	.000	.000	90.000
44	.000	25.000	.001	360.000	.000	.000	-90.000
45	56.000	136.000	.000	30.700	-13.610	.000	-90.000
46	-136.000	-56.000	149.300	180.000	13.610	.000	90.000
47	.000	92.400	.001	180.000	-13.610	-30.700	.000
48	.000	92.400	.001	180.000	13.610	-30.700	.000
49	.001	180.000	.001	360.000	.000	.000	.000
50	.001	180.000	.001	360.000	.000	.000	.000

Table 2-1

Helicopter Geometrical Structure Data (Cont.)

SURFACE NUMBER	HELICOPTER PART DESCRIPTION	SURFACE TYPE	FLIGHT STATION	WATER-LINE	BULKHEAD LINE	ALPHA
51	FRONT WINDOW	TRAPESOID	54.920	-181.000	.000	.000
52	TOP FRONT	CYLINDER	-92.700	40.000	.000	14.000
53	L. FRONT SIDE WINDOW	RECTANGLE	-92.700	40.000	46.200	.000
54	R. FRONT SIDE WINDOW	RECTANGLE	-92.700	40.000	-46.200	.000
55	L. BOTTOM SIDE WINDOW	DISC	-46.500	-15.000	35.010	.000
56	R. BOTTOM SIDE WINDOW	DISC	-46.500	-15.000	-35.010	.000
57	L. BOTTOM FRONT WINDOW	CYLINDER	-46.500	-15.000	.000	25.010
58	R. BOTTOM FRONT WINDOW	CYLINDER	-46.500	-15.000	.000	25.010
59	L. ENGINE NOSE	SPHERE	-456.000	68.000	47.000	8.000
60	R. ENGINE NOSE	SPHERE	-456.000	68.000	-47.000	8.000
61	L. ENGINE SHAFT	CYLINDER	-456.000	68.000	47.000	8.000
62	R. ENGINE SHAFT	CYLINDER	-456.000	68.000	-47.000	8.000
63	L. ENGINE INTAKE	DISC	-472.000	68.000	47.000	.000
64	R. ENGINE INTAKE	DISC	-472.000	68.000	-47.000	.000
65	1ST SECTION L. ENGINE	CONE	-416.000	68.000	47.000	12.100
66	1ST SECTION R. ENGINE	CONE	-416.000	68.000	-47.000	12.100
67	2ND SECTION L. ENGINE	CONE	-642.000	68.000	47.000	5.500
68	2ND SECTION R. ENGINE	CONE	-642.000	68.000	-47.000	5.500
69	L. ENGINE TAIL CONE	CONE	-387.000	68.000	47.000	3.800
70	R. ENGINE TAIL CONE	CONE	-387.000	68.000	-47.000	3.800
71	L. ENGINE REAR	DISC	-554.000	68.000	47.000	.000
72	R. ENGINE REAR	DISC	-554.000	68.000	-47.000	.000
73	FWD FRONT SAIL	CYLINDER	-104.000	40.000	.000	24.000
74	FRONT ROTOR HUB	DISC	-104.000	40.000	.000	50.000
75	L. SIDE FRONT SAIL	TRAPESOID	-434.000	40.000	-46.000	.000

Table 2-1

Helicopter Geometrical Structure Data (Cont.)

SURFACE NUMBER	BETA-MIN	BETA-MAX	GAMMA-MIN	GAMMA-MAX	PSI	THETA	PHI
51	-265.900	-173.500	173.080	186.920	-90.000	.000	-59.300
52	-32.190	32.190	.001	360.000	.000	.000	90.000
53	.000	24.000	.000	60.000	-13.610	59.300	-90.000
54	-24.000	.000	.000	60.000	13.610	59.300	90.000
55	.000	25.000	30.000	60.000	.000	.000	-90.000
56	.000	25.000	120.000	150.000	.000	.000	90.000
57	10.000	35.000	30.000	60.000	.000	.000	-90.000
58	10.000	35.000	30.000	60.000	-90.000	90.000	.000
59	.001	180.000	.001	360.000	.000	.000	.000
60	.001	180.000	.001	360.000	.000	.000	.000
61	.000	16.000	.001	360.000	.000	-90.000	.000
62	.000	16.000	.001	360.000	.000	-90.000	.000
63	.000	12.000	.001	360.000	.000	90.000	.000
64	.000	12.000	.001	360.000	.000	90.000	.000
65	56.000	70.000	.001	360.000	.000	-90.000	.000
66	56.000	70.000	.001	360.000	.000	-90.000	.000
67	104.000	156.000	.001	360.000	.000	90.000	.000
68	104.000	156.000	.001	360.000	.000	90.000	.000
69	130.000	167.000	.001	360.000	.000	-90.000	.000
70	130.000	167.000	.001	360.000	.000	-90.000	.000
71	.000	11.060	.001	360.000	.000	-90.000	.000
72	.000	11.060	.001	360.000	.000	-90.000	.000
73	-10.000	50.000	.001	180.000	.000	.000	.000
74	.000	24.000	.001	180.000	.000	.000	.000
75	270.000	337.500	.000	8.350	-90.000	-90.000	11.880

Table 2-1

Helicopter Geometrical Structure Data (Cont.)

SURFACE NUMBER	HELICOPTER PART DESCRIPTION	SURFACE TYPE	FLIGHT STATION	WATER-LINE	BULKHEAD LINE	ALPHA
76	R. SIDE FRONT SAIL	TRAPESOID	-434.000	40.000	46.000	.000
77	TOP FRONT SAIL	TRAPESOID	-217.100	72.860	.000	.000
78	REAR FRONT SAIL	CYLINDER	-170.000	40.000	.000	10.000
79	REAR TOP FRONT SAIL	DISC	-170.000	40.000	.000	40.000
80	1ST BLADE FRONT ROTOR	RECTANGLE	-104.000	90.000	.000	.000
81	2ND BLADE FRONT ROTOR	RECTANGLE	-104.000	90.000	.000	.000
82	3RD BLADE FRONT ROTOR	RECTANGLE	-104.000	90.000	.000	.000
83	MID AFT SAIL	CYLINDER	-550.000	145.000	.000	20.000
84	AFT ROTOR HUB	DISC	-550.000	145.000	.000	.000
85	L. FWD SIDE AFT SAIL	TRAPESOID	.000	45.000	-30.000	.000
86	R. FWD SIDE AFT SAIL	TRAPESOID	.000	45.000	30.000	.000
87	FWD TOP AFT SAIL	TRAPESOID	-330.000	105.000	.000	.000
88	FRONT AFT SAIL	CYLINDER	-440.000	45.000	.000	10.000
89	TOP FRONT AFT SAIL	DISC	-440.000	45.000	.000	80.000
90	L. REAR AFT SAIL	RECTANGLE	-630.500	145.000	.000	.000
91	R. REAR AFT SAIL	RECTANGLE	-630.500	145.000	.000	.000
92	TOP REAR AFT SAIL	TRAPESOID	-630.500	145.000	.000	.000
93	1ST BLADE AFT ROTOR	RECTANGLE	-550.000	145.000	.000	.000
94	2ND BLADE AFT ROTOR	RECTANGLE	-550.000	145.000	.000	.000
95	3RD BLADE AFT ROTOR	RECTANGLE	-550.000	145.000	.000	.000
96	L. FRONT OF ENGINE STRUT	CYLINDER	-456.000	68.000	47.000	3.000
97	R. FRONT OF ENGINE STRUT	CYLINDER	-456.000	68.000	-47.000	3.000
98	L. TOP OF ENGINE STRUT	RECTANGLE	-471.000	68.000	47.000	.000
99	R. TOP OF ENGINE STRUT	RECTANGLE	-471.000	68.000	-47.000	.000
A0	L. BOT OF ENGINE STRUT	RECTANGLE	-471.000	68.000	47.000	.000

Table 2-1

Helicopter Geometrical Structure Data (Cont.)

SURFACE NUMBER	BETA-MIN	BETA-MAX	GAMMA-MIN	GAMMA-MAX	PSI	THETA	PHI
76	-337.500	-270.000	171.650	180.000	90.000	-90.000	-11.880
77	-114.410	-47.590	168.190	191.810	90.000	.000	-8.620
78	.000	40.000	.001	360.000	.000	.000	.000
79	.000	10.000	.001	360.000	.000	.000	.000
80	-25.000	.000	.000	372.000	.000	8.000	.000
81	-25.000	.000	.000	372.000	120.000	-4.000	7.000
82	-25.000	.000	.000	372.000	-120.000	-4.000	-7.000
83	-100.000	.000	.001	360.000	.000	.000	.000
84	.000	20.000	.001	360.000	.000	.000	.000
85	-550.000	-440.000	169.710	180.000	-90.000	-90.000	-5.200
86	-550.000	-440.000	180.000	190.290	-90.000	90.000	-5.200
87	-224.200	-112.100	174.925	185.075	-90.000	.000	-10.290
88	.000	80.000	.001	360.000	.000	.000	.000
89	.000	10.000	.001	360.000	.000	.000	.000
90	-83.000	.000	.000	91.000	90.000	90.000	-14.000
91	-83.000	.000	-91.000	.000	90.000	-90.000	-14.000
92	-80.500	.000	166.000	194.000	90.000	.000	.000
93	.000	25.000	.000	372.000	.000	3.400	.000
94	.000	25.000	.000	372.000	120.000	-1.700	2.940
95	.000	25.000	.000	372.000	-120.000	-1.700	-2.940
96	.000	48.000	.001	360.000	.000	.000	106.600
97	.000	48.000	.001	360.000	.000	.000	-106.600
98	-48.000	.000	.000	15.300	.000	11.300	10.600
99	.000	48.000	.000	15.300	.000	11.300	-10.600
A0	-48.000	.000	.000	15.300	.000	-11.300	10.600

Table 2-1

Helicopter Geometrical Structure Data (Cont.)

SURFACE NUMBER	HELICOPTER PART DESCRIPTION	SURFACE TYPE	FLIGHT STATION	WATER-LINE	BULKHEAD LINE	ALPHA
A1	R. BOT OF ENGINE STRUT	RECTANGLE	-471.000	68.000	-47.000	.000
A2	TOP DRIVE SHAFT HOUSING	RECTANGLE	-104.000	60.000	.000	.000
A3	L. SIDE DR. SH. HOUSING	RECTANGLE	-104.000	60.000	20.000	.000
A4	R. SIDE DR. SH. HOUSING	RECTANGLE	-104.000	60.000	-10.000	.000
A5	L. ENGINE CRADLE	CONE	-486.000	81.000	54.000	30.000
A6	R. ENGINE CRADLE	CONE	-486.000	81.000	-54.000	30.000
A7	L. UPPER FUSELAGE JOINT	SPHERE	-125.000	40.000	40.000	14.000
A8	R. UPPER FUSELAGE JOINT	SPHERE	-125.000	40.000	-40.000	14.000
A9	L. FWD TOP CURVD FUSE.	CYLINDER	-92.700	40.000	32.190	14.000
B0	R. FWD TOP CURVD FUSE.	CYLINDER	-92.700	40.000	-32.190	14.000
B1	TOP FRONT FUSELAGE	TRAPEZOID	40.250	54.000	.000	.000
B2	FWD BOTTOM FUSELAGE	TRAPEZOID	98.200	-40.000	.000	.000

Table 2-1

Helicopter Geometrical Structure Data (Cont.)

SURFACE NUMBER	BETA-MIN	BETA-MAX	GAMMA-MIN	GAMMA-MAX	PSI	THETA	PHI
A1	.000	48.000	.000	15.300	.000	-11.300	-10.600
A2	-10.000	20.000	-446.000	.000	.000	.000	.000
A3	.000	6.000	-446.000	.000	.000	.000	-90.000
A4	-6.000	.000	-446.000	.000	.000	.000	90.000
A5	.000	41.000	.001	360.000	.000	.000	150.000
A6	.000	41.000	.001	360.000	.000	.000	-150.000
A7	.001	180.000	.001	300.000	.000	.000	.000
A8	.001	180.000	.001	300.000	.000	.000	.000
A9	.000	33.200	.001	90.000	-13.610	-90.000	.000
B0	.000	33.200	90.000	180.000	13.610	-90.000	.000
B1	-165.250	-132.950	166.390	193.610	-90.000	.000	.000
B2	-223.200	-144.700	166.390	193.610	-90.000	.000	.000

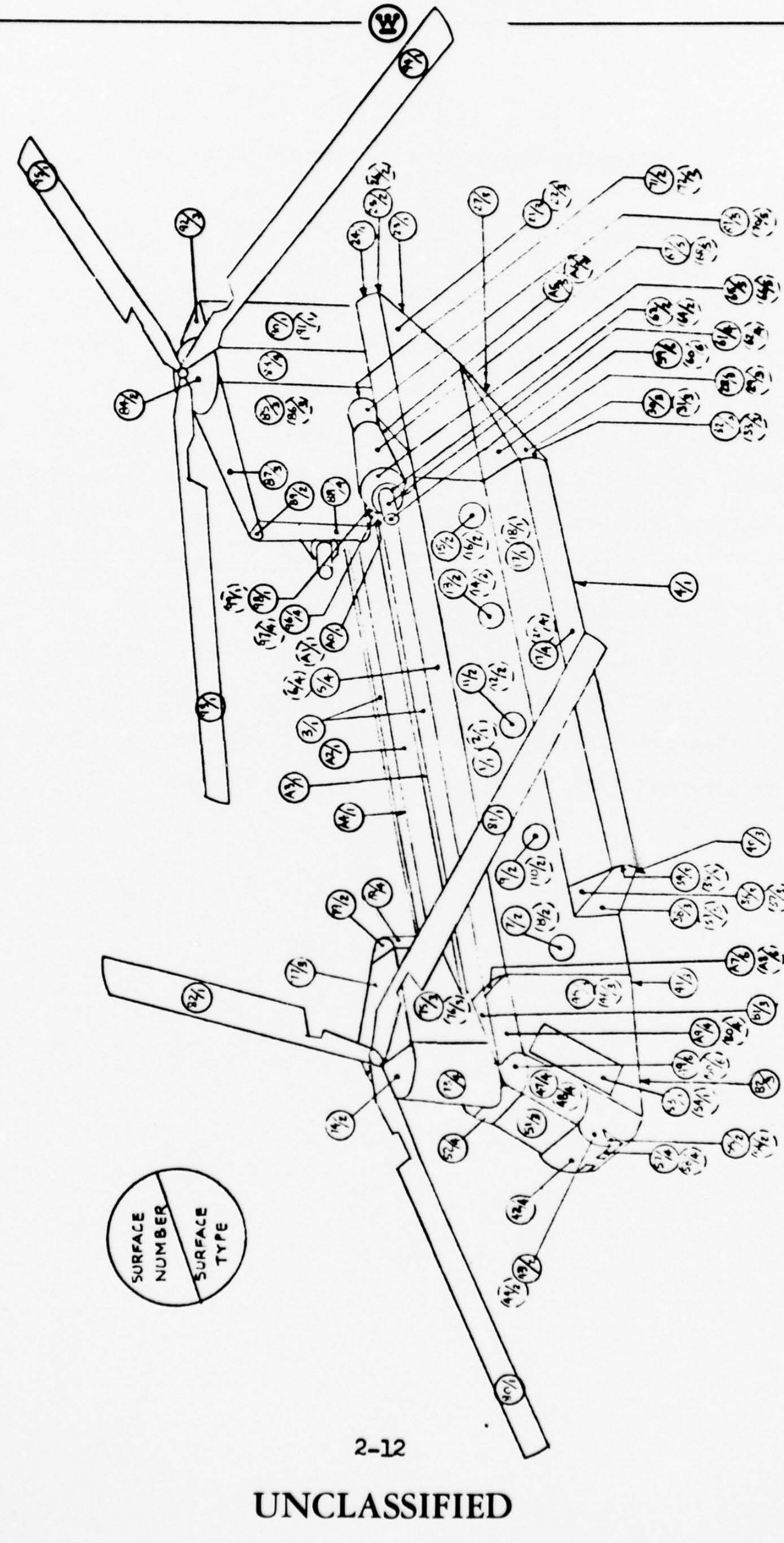
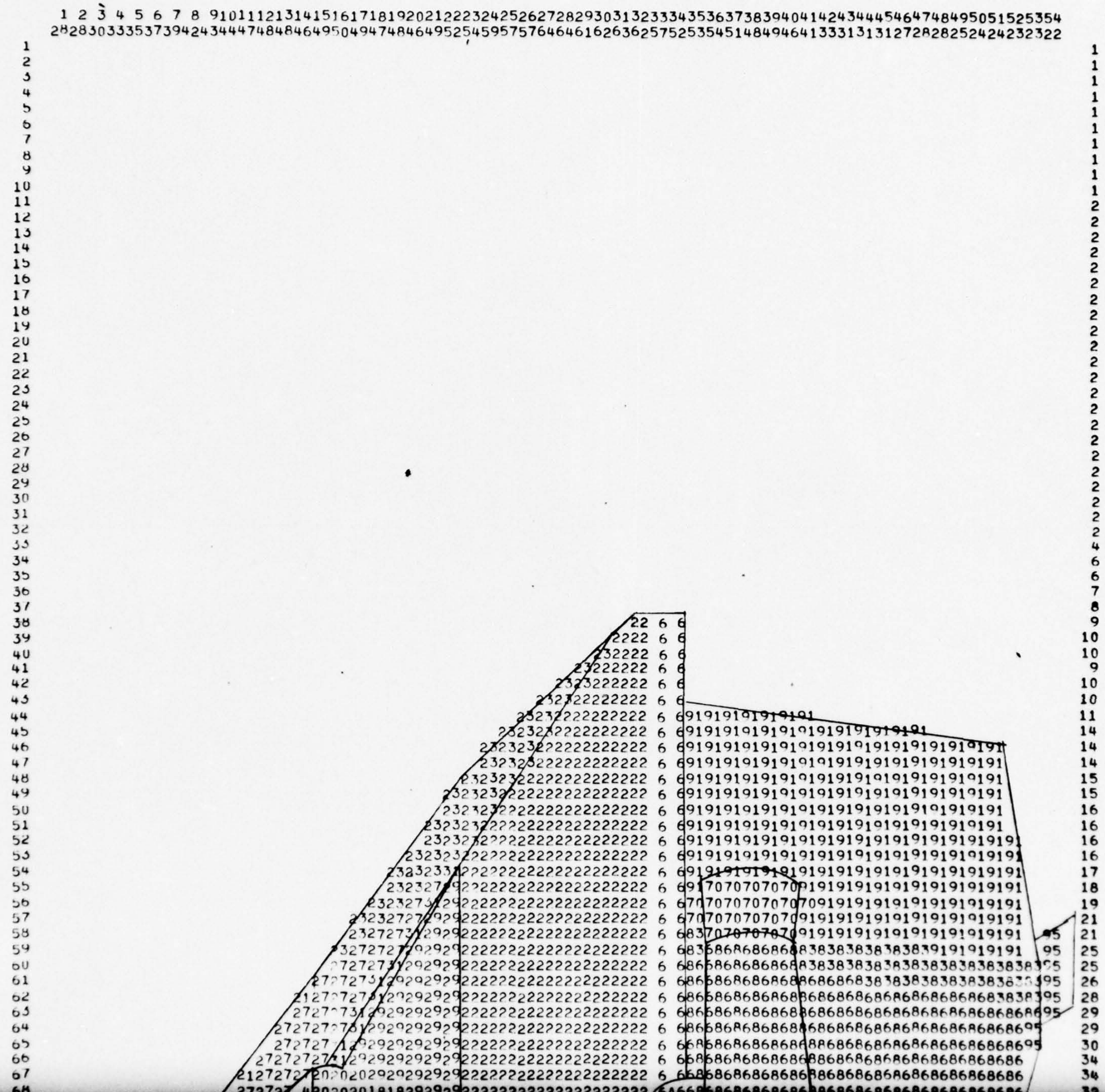
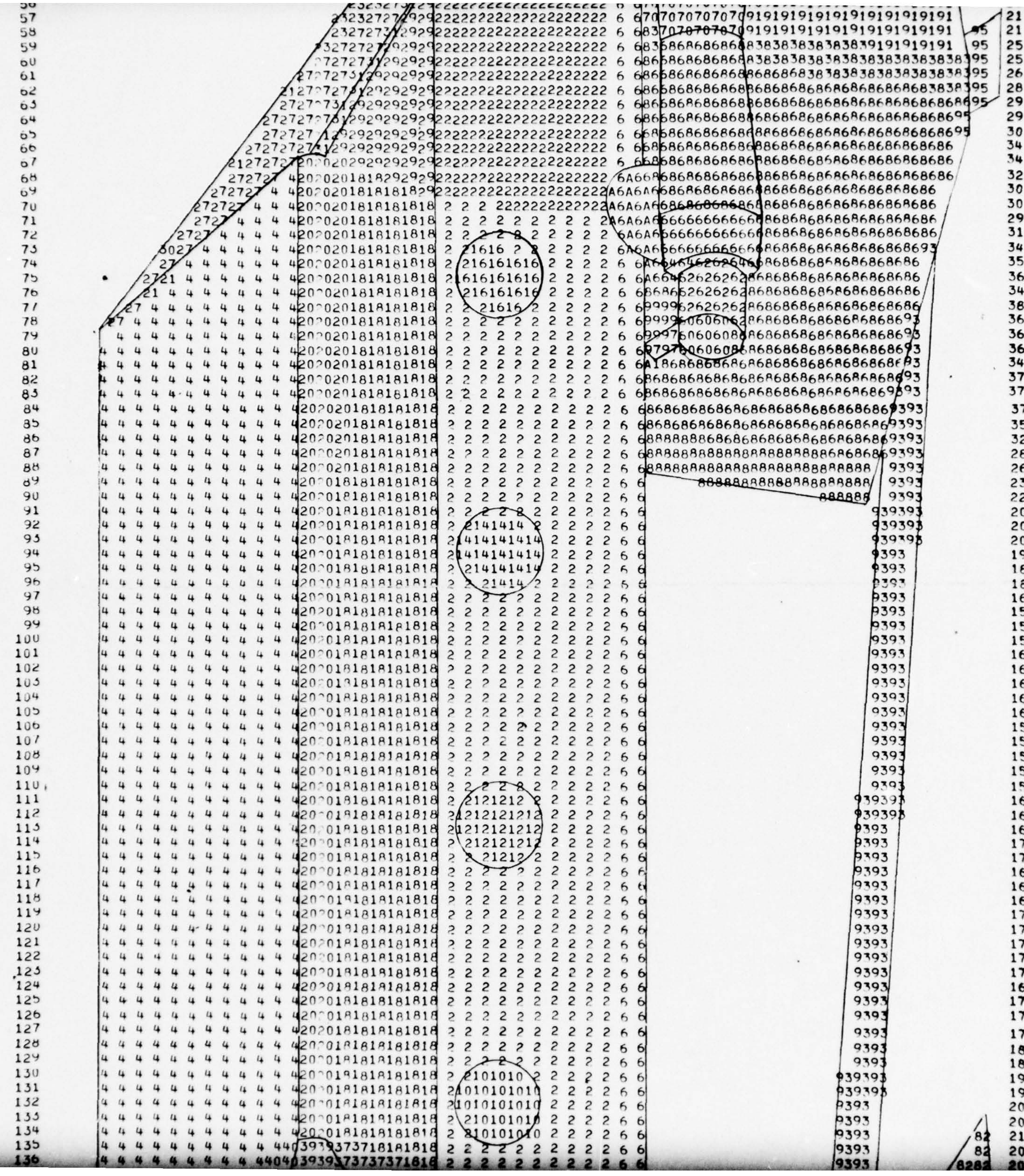


Figure 2-1. CH-47 Surface Location





2

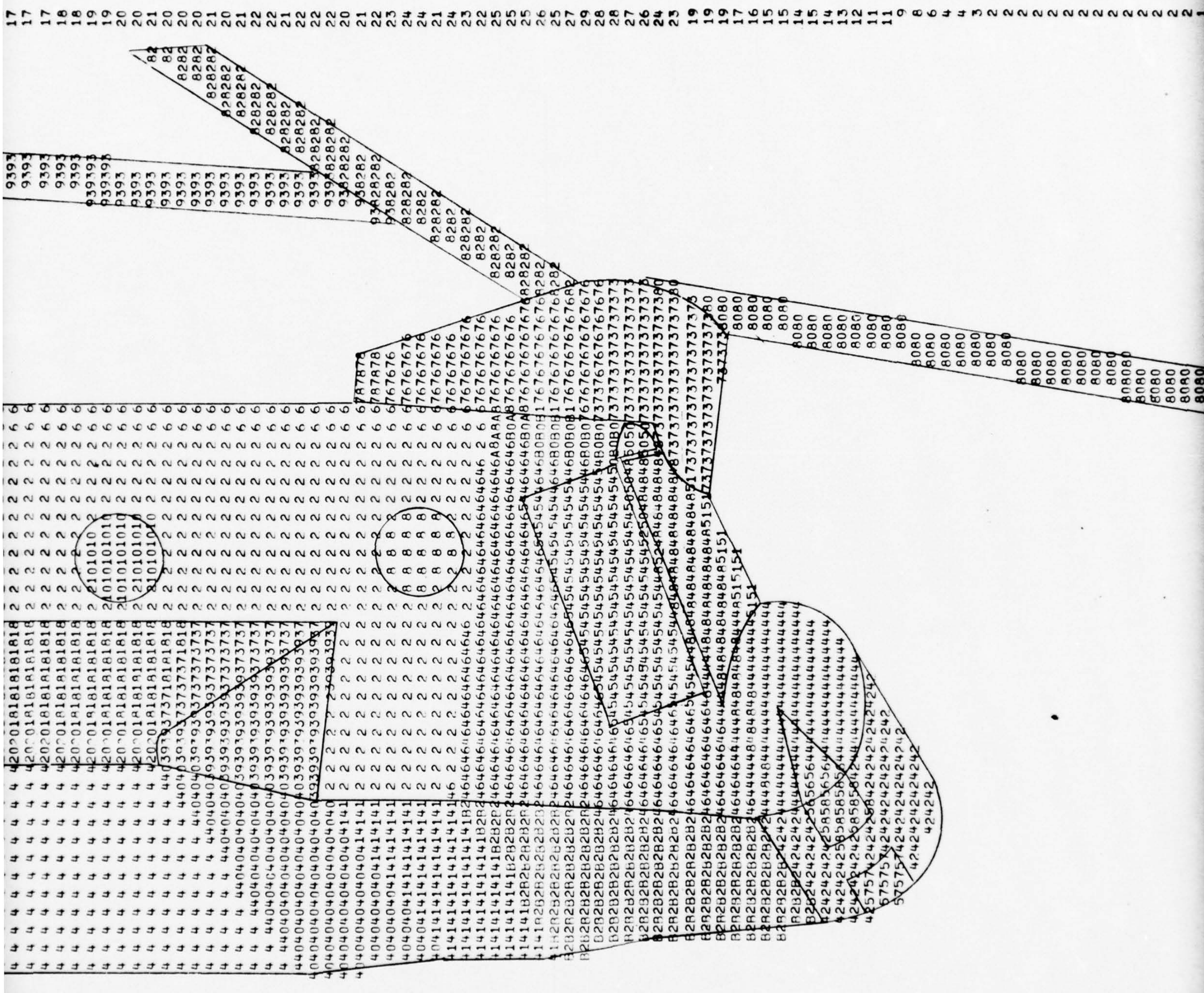
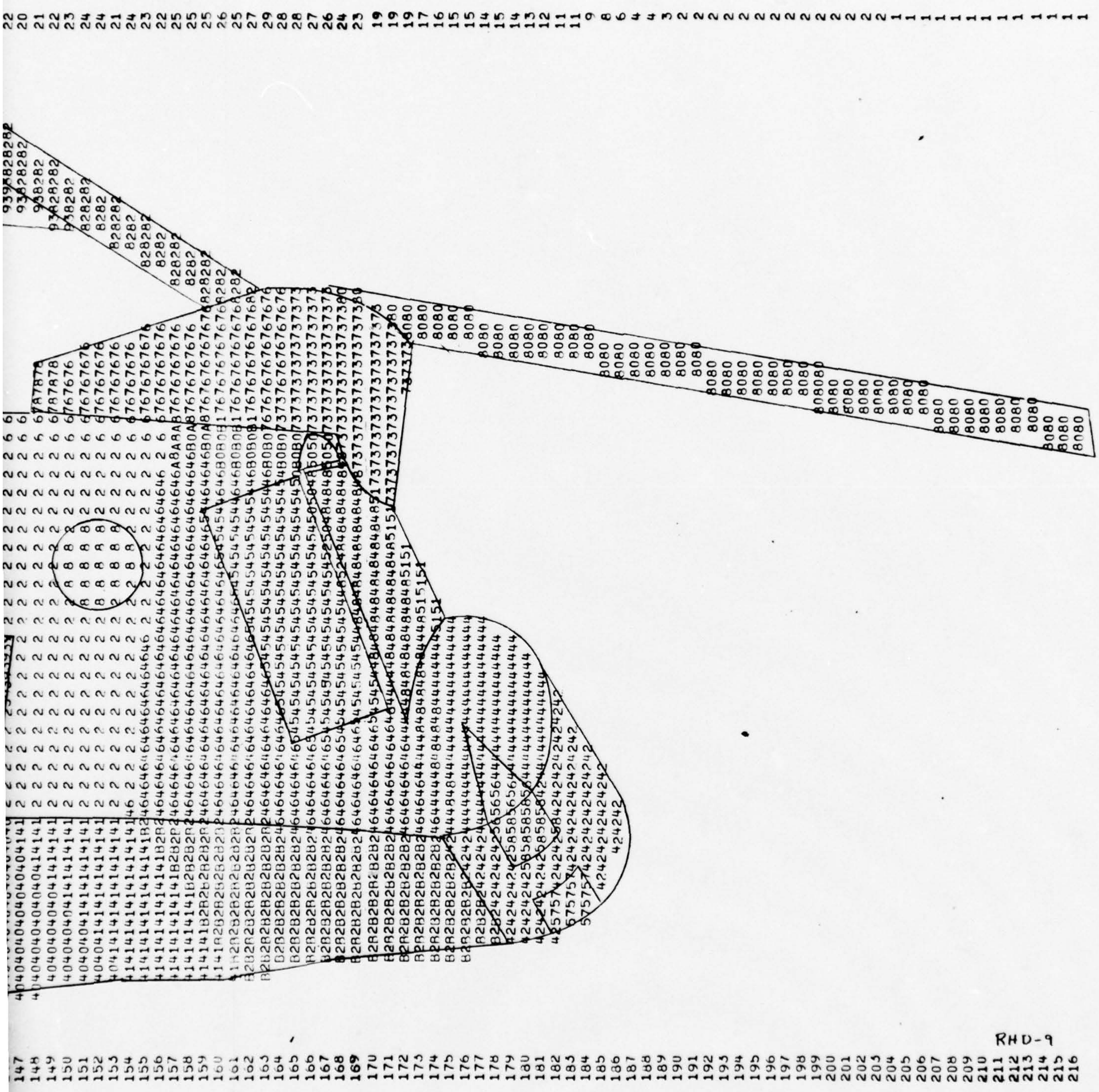


Figure 2-2. (U) CH-47 Printout @ 70° Aspect With
Left Roll

3



RHD-9

Figure 2-2. (U) CH-47 Printout @ 70° Aspect With 20° Left Roll

4

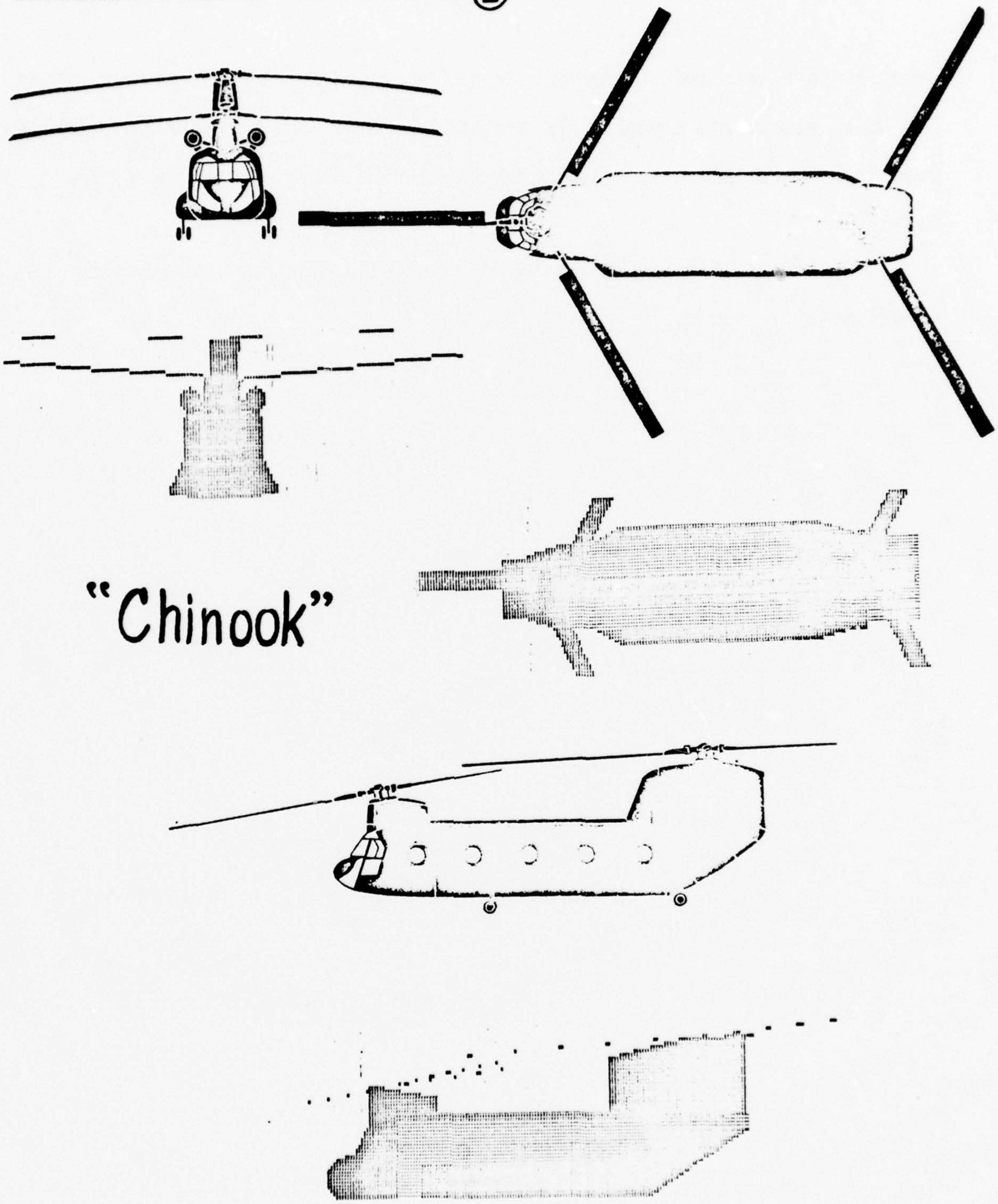


Figure 2-3. (U) CH-47 Silhouette Comparisons

printout have been reduced in size to the scale of a three-view drawing from the CH-47 operator's manual. The individual numbers have become too small to read, but the silhouettes compare favorably with those of the three view drawing.

A listing of the body Block Data in the HIDE Model is presented in Appendix A.

3.0 (U) HELICOPTER OPERATING CHARACTERISTICS AND TURBINE DATA

The HIDE Model requires certain data which describes the plume exit from the tailpipe. This data is computed in an off-line program using inputs which describe the helicopter operating characteristics and the turbine. The input data for the off-line program is presented in tabular form in this section. A listing of the off-line program and its block data are presented in Appendix B.

3.1 (U) HELICOPTER OPERATING CHARACTERISTICS

The operating characteristics for the CH-47 helicopter are presented in tabular form in Tables 3-1 through 3-4. Table 3-1 presents speed and torque data as a function of pressure altitude for best range speed. Tables 3-2, 3-3 and 3-4 present similar data for maximum cruise speed, maximum endurance, and hovering endurance flight, respectively.

The original data from the CH-47 Operator's Manual from which Tables 3-1 to 3-4 were generated are shown in Appendix C. They include a table showing pressure altitude as a function of density altitude and temperature, and four charts showing true air speed and torque for various combinations of pressure altitude and gross weight. In addition, a table for converting torque to shaft horsepower is included.

3.2 (U) TURBINE DATA

The CH-47 uses two Lycoming Model T55-L-7 turbines. The data from this engine is presented in tabular form in Tables 3-5 through 3-7. Table 3-5 shows air flow (Wa), fuel flow (Wf) and net thrust (Fg) for various combinations of altitude and shaft horsepower (SHP) settings. Table 3-6 shows Turbine outlet temperature versus shaft horsepower. Table 3-7 presents correction factors for air flow, fuel flow, and net thrust as a function of ambient temperature.

The original data from the Lycoming manual from which tables 3-5 through 3-7 were generated is shown in Appendix D. They include performance curves for altitudes of 0, 5000, 10,000, 15,000, and 20,000 feet, an outlet temperature curve and ambient temperature correction curves.

Table 3-1. CH-47 Helicopter Speed and Torque Data for Best Range Speed

Pres. Alt. (ft.)	Gross Weight: 20000 to 24000 lbs. Torque (lb-ft)	Gross Weight: 20000 to 24000 lbs. Speed (Knots)	Gross Weight: 24001 to 28000 lbs. Torque (lb-ft)	Gross Weight: 24001 to 28000 lbs. Speed (Knots)
0	606	140	661	142
2000	579	140	624	142
4000	555	139	606	141
6000	538	139	585	141
8000	515	139	566	140
10000	499	138	555	138
12000	486	137	546	136
14000	427	125	489	125
15000	390	118	461	118

Pres. Alt. (ft.)	Gross Weight: 28001 to 32000 lbs. Torque (lb-ft)	Gross Weight: 28001 to 32000 lbs. Speed (Knots)	Gross Weight: 32001 to 34000 lbs. Torque (lb-ft)	Gross Weight: 32001 to 34000 lbs. Speed (Knots)
0	687	143	711	143
2000	678	143	686	143
4000	658	142	678	141
6000	635	141	659	139
8000	621	138	631	134
10000	604	135	603	127
12000	575	127	505	104
14000	496	103		
15000	470	88		

Pres. Alt. (ft.)	Gross Weight: 34001 to 36000 lbs. Torque (lb-ft)	Gross Weight: 34001 to 36000 lbs. Speed (Knots)	Gross Weight: 36001 to 38000 lbs. Torque (lb-ft)	Gross Weight: 36001 to 38000 lbs. Speed (Knots)
0	734	143	753	144
2000	709	142	720	134
4000	689	140	689	127
6000	658	135	658	115
8000	631	127	631	103
10000	603	115	603	93
12000	522	89		

Table 3-1. (Cont'd) CH-47 Helicopter Speed and Torque Data for Best Range Speed		
	Gross Weight: 38001 to 40000 lbs.	
Pres. Alt. (Ft.)	Torque (lb-ft)	Speed (Knots)
0	653	125
2000	628	122
4000	599	113
6000	527	100
8000	568	87

Table 3-2. CH-47 Helicopter Speed and Torque Data for Maximum Cruise Speed				
	Gross Weight: 20000 to 24000 lbs.		Gross Weight: 24001 to 28000 lbs.	
Pres. Alt. (ft.)	Torque (lb-ft)	Speed (Knots)	Torque (lb-ft)	Speed (Knots)
0	753	154	753	152
2000	720	154	720	152
4000	689	154	689	151
6000	658	153	658	149
8000	617	151	631	147
10000	555	146	603	145
12000	486	137	538	137
14000	427	125	489	125
15000	390	118	462	118
	Gross Weight: 28001 to 32000 lbs.		**Gross Weight: 32001 to 34000 lbs.**	
Pres. Alt. (ft.)	Torque (lb-ft)	Speed (Knots)	Torque (lb-ft)	Speed (Knots)
0	753	149	753	148
2000	720	148	720	146
4000	689	146	689	143
6000	658	143	658	140
8000	631	140	631	134
10000	603	135	603	127
12000	575	127	505	104
14000	494	103		
15000	470	88		

Table 3-2. (Cont'd) CH-47 Helicopter Speed and Torque Data for Maximum Cruise Speed

Pres. Alt. (ft.)	Gross Weight: 34001 to 36000 lbs. Torque (lb-ft)	Gross Weight: 34001 to 36000 lbs. Speed (Knots)	Gross Weight: 36001 to 38000 lbs. Torque (lb-ft)	Gross Weight: 36001 to 38000 lbs. Speed (Knots)
0	753	145	753	143
2000	720	143	720	139
4000	689	140	689	134
6000	658	135	658	128
8000	631	127	631	118
10000	603	115	603	101
12000	522	89		

Pres. Alt. (ft.)	Gross Weight: 38001 to 4000 lbs. Torque (lb-ft)	Gross Weight: 38001 to 4000 lbs. Speed (Knots)
0	653	125
2000	629	122
4000	599	113
6000	527	100
8000	568	87

Table 3-3. CH-47 Helicopter Speed and Torque Data for Maximum Endurance

Pres. Alt. (ft.)	Gross Weight: 20000 to 24000 lbs. Torque (lb-ft)	Gross Weight: 20000 to 24000 lbs. Speed (Knots)	Gross Weight: 24001 to 28000 lbs. Torque (lb-ft)	Gross Weight: 24001 to 28000 lbs. Speed (Knots)
0	312	69	361	75
2000	311	72	361	77
4000	311	74	361	78
6000	312	76	361	79
8000	312	77	362	80
10000	313	78	365	81
12000	314	79	370	81
14000	316	80	377	82
15000	318	80	383	82

Table 3-3. (Cont'd) CH-47 Helicopter Speed and Torque Data for Maximum Endurance

Pres. Alt. (ft.)	Gross Weight: 28001 to 32000 lbs. Torque (lb-ft)	Gross Weight: 28001 to 32000 lbs. Speed (Knots)	Gross Weight: 32001 to 34000 lbs. Torque (lb-ft)	Gross Weight: 32001 to 34000 lbs. Speed (Knots)
0	409	78	434	80
2000	410	80	435	81
4000	413	80	437	81
6000	413	81	441	82
8000	418	82	451	82
10000	426	82	465	82
12000	441	82	491	82
14000	467	82		
15000	483	82		

Pres. Alt. (ft.)	Gross Weight: 34001 to 36000 lbs. Torque (lb-ft)	Gross Weight: 34001 to 36000 lbs. Speed (Knots)	Gross Weight: 36001 to 38000 lbs. Torque (lb-ft)	Gross Weight: 36001 to 38000 lbs. Speed (Knots)
0	459	81	485	82
2000	461	81	489	82
4000	465	82	497	83
6000	474	83	511	83
8000	489	83	536	83
10000	515	83	572	83
12000	550	82		

Pres. Alt. (ft.)	Gross Weight: 38001 to 40000 lbs. Torque (lb-ft)	Gross Weight: 38001 to 40000 lbs. Speed (Knots)
0	513	82
2000	520	83
4000	534	83
6000	557	83
8000	592	83

Table 3-4. CH-47 Helicopter Speed and Torque Data for Hovering Endurance

Pres. Alt. (ft.)	Gross Weight: 20000 to 24000 lbs. Torque (lb-ft)	Gross Weight: 20000 to 24000 lbs. Speed (Knots)	Gross Weight: 24001 to 28000 lbs. Torque (lb-ft)	Gross Weight: 24001 to 28000 lbs. Speed (Knots)
0	441	0	522	0
2000	441	0	530	0
4000	443	0	540	0
6000	449	0	559	0
8000	457	0	563	0
10000	466	0	577	0
12000	477	0	592	0
14000	488	0	610	0

Pres. Alt. (ft.)	Gross Weight: 28001 to 32000 lbs. Torque (lb-ft)	Gross Weight: 28001 to 32000 lbs. Speed (Knots)	Gross Weight: 32001 to 34000 lbs. Torque (lb-ft)	Gross Weight: 32001 to 34000 lbs. Speed (Knots)
0	621	0	674	0
2000	634	0	689	0
4000	648	0	705	0
6000	663	0	723	0
8000	680	0	744	0
10000	700	0		

Pres. Alt. (ft.)	Gross Weight: 34001 to 36000 lbs. Torque (lb-ft)	Gross Weight: 34001 to 36000 lbs. Speed (Knots)	Gross Weight: 36001 to 38000 lbs. Torque (lb-ft)	Gross Weight: 36001 to 38000 lbs. Speed (Knots)
0	729	0	786	0
2000	746	0	805	0
4000	765	0		
6000	786	0		

Pres. Alt. (ft.)	Gross Weight: 38001 to 40000 lbs. Torque (lb-ft)	Gross Weight: 38001 to 40000 lbs. Speed (Knots)
0	845	0

Table 3-5. Engine Parameters at Standard Ambient Temperature

SHP	Altitude: Sea Level Wa (lb/sec)	Wf (lb/hr)	Fg (lb)	Altitude: 5000 Feet Wa (lb/sec)	Wf (lb/hr)	Fg (lb)
500	14.3	560	75	12.6	510	60
1000	16.5	810	100	14.6	750	95
1500	17.7	1020	130	16.75	985	130
2000	20	1240	165	17.3	1200	165
2500	21.5	1460	200	18.8	1450	200

SHP	Altitude: 10,000 Feet Wa (lb/sec)	Wf (lb/hr)	Fg (lb)	Altitude: 15,000 Feet Wa (lb/sec)	Wf (lb/hr)	Fg (lb)
500	11.1	470	60	9.7	415	50
1000	12.9	700	95	11.5	650	80
1500	14.55	920	125	13.0	880	115
2000	15.75	1160	160	13.8	1120	160
2500	16.4	1400	190	13.7	1300	215

SHP	Altitude: 20,000 Feet Wa (lb/sec)	Wf (lb/hr)	Fg (lb)
500	8.8	380	50
1000	10.2	600	90
1500	11.3	840	125

Table 3.6. Referred Power Turbine Outlet Total Temperature Versus Referred Shaft Horsepower

$SHP/\delta_{amb}\sqrt{\theta_{amb}}$	T_{to}/θ_{amb}*
1000	1360
1500	1425
2000	1505
2500	1595
3000	1700
3500	1805
4000	1940

*Note: θ_{amb} = relative temperature ratio = $\frac{T_{amb} \text{ @ altitude } (^{o}R)}{519}$

Table 3.7. Ambient Temperature Correction Factors (100% normal rated power)

Tamb (^{o}R)	$\frac{\Delta Wa}{Wa}$	$\frac{\Delta Wf}{Wf}$	$\frac{\Delta Fg}{amb}$
420	0.260	0.360	80
440	0.215	0.295	60
460	0.160	0.215	35
480	0.108	0.148	25
500	0.053	0.065	10
520	0.000	-0.005	0
540	-0.058	-0.070	-12
560	-0.110	-0.135	-25
580	-0.162	-0.200	-40

4.0 (U) CH-47 SIGNATURE

The CH-47 surface data derived and listed in Table 2-1 was put into the HIDE model in the form of "block data" as given in Appendix A. The CH-47 turbine model (listed in Appendix B) was then run off line to derive inputs for the HIDE model. Meteorologic and operating conditions were selected and the HIDE program executed to generate a CH-47 signature.

The generation of a viable signature represents the completion of the CH-47 model construction. This section describes a typical signature.

4.1 (U) INPUT DATA

The input data that was used to obtain the sample signature is given in Table 4-1.

The identification of the variable names and their units are as follows:

TAIR = Ambient air temperture, degrees Kelvin
PRESS = Ambient pressure, millibars
RMIX = Mixing ratio, gms H_2O/Kgm dry air
VISR = Visual range, KM
CFRA = Cloud fraction, tenths
IDAY = Flag, 1 = night, 2 = day
AZSUN = Azimuth of sun relative to LOS, degrees
ZESUN = Zenith of sun, degrees
WINDVL = Wind velocity, ft/sec
WANGLE = Compass heading of wind origin, degrees
RGND = Reflectivity of ground
ENGD = Emissivity of ground
TGND = Temperature of ground
RCLD = Reflectivity of cloud
HT = Helicopter height, KM
PSIH = Helicopter yaw relative to East, degrees
SPEEDH = Helicopter speed, ft/sec
YAWV = Helicopter velocity vector yaw relative to air frame, degrees
PITCHV = Helicopter velocity vector pitch relative to air frame, degrees

ROLLV = Helicopter velocity vector roll relative to air frame, degrees
AMT = Atmospheric pressure, atmospheres
AIRTMP = Air temperature at helicopter altitude, deg. Kelvin
FEFF = Combustion efficiency
FHTOC = Hydrogen to carbon ratio of fuel
FATOMS = Number of carbon atoms in fuel molecule
QQ1 = 1 + fuel to air ratio
XTMP = Exit gas temperature
AIRH2O = Partial pressure of water vapor in air, percent
AIRCO2 = Partial pressure of carbon dioxide in air, percent
XH2O = Partial pressure of water vapor in exhaust gas, percent
XCO2 = Partial pressure of carbon dioxide in exhaust gas percent
AIRCP = Specific heat of air
EXVEL = Velocity of exit gas, ft/sec
DOWNSH = Down wash velocity, ft/sec
DE = Exit diameter, inches
R = Range, KM
HO = Observer height, KM
HX = Helicopter position in earth coordinate system (EAST), inches
HY = Helicopter position in earth coordinate system (NORTH), inches
HZ = Helicopter position in earth coordinate system (ELEVATION), inches
OX = Observer position in earth coordinate system (EAST), inches
OY = Observer position in earth coordinate system (NORTH), inches
OZ = Observer position in earth coordinate system (ELEVATION), inches
PSIO = LOS yaw angle, degrees
THETAO = LOS pitch angle, degrees
PHIO = LOS roll angle, degrees
TPTMP = Temperature of tailpipes
TPEMS = Emissivity of tailpipes
COVER = Flag, 0 = no suppressor, 1 = suppressor
FOVX = Observer field of view in azimuth, degrees
FOVY = Observer field of view in elevation, degrees
ANGX = Angular resolution in azimuth, degrees
ANGY = Angular resolution in elevation, degrees
LOW = Short wave length index
LHI = Long wave length index
BIASK = Azimuth displacements of LOS from center of gravity, resolution elements
BIASJ = Elevation displacement of LOS from center of gravity, resolution elements
CHIT = Cloud height
ECLD = Emissivity of cloud
PRD = Log plot scale factor

TABLE 4-1. (U) INPUT DATA

```
       TETHERED CH-47      ASPECT 159
 1
   TAIR   =  .28700000E+03  PRESS =  .10130000E+04  RMIX   =  .23250000E+01
   VISR   =  .70000000E+01  CFRA  = 0.                IDAY   =  .20000000E+01
   AZSUN  =  .31900000E+03  ZENSUN=  .66000000E+02  WINDVL=  .10000000E-01
   WANGLE= 0.                RGND  =  .70000000E-01  EGND   =  .93000000E+00
   TGND   =  .28700000E+03  RCLD  =  .10000000E+01  HT(1)  =  .12500000E-01
   PSIH   =  .35000000E+03  THETAH= -.17000000E+02  PHIH   = 0.
   SPEEDH= 0.                YAWV  = 0.              PITCHV= 0.
   ROLLV  = 0.               ATM   =  .91700000E+00  AIRTMP=  .28700000E+03
   FEFF   =  .95000000E+00  FHTOC =  .20000000E+01  FATOMS=  .70000000E+01
   QQ1    =  .10180000E+01  XTMP  =  .34800000E+03  AIRH2O=  .10000000E-02
   AIFCO2=  .32000000E-03  XH2O  =  .30000000E-01  XCO2   =  .30000000E-01
   XCF    =  .26600000E+00  AIRCP =  .24000000E+00  EXVEL  =  .27800000E+03
   DOWNSH=  .23000000E+02  DE    =  .22600000E+02  P(1)   =  .83900000E-01
   HO(1)  =  .10000000E-02  HX    =  .33200000E+04  HY     =  .64000000E+03
   HZ     =  .49600000E+03  OX    = 0.              OY     = 0.
   OZ     =  .39370000E+02  PSIO  =  .11000000E+02  THETAO= 0.
   PHIO   = 0.               TPTMP =  .74800000E+03  TPEMS  =  .40000000E+00
   COVER  = 0.               FOVX  =  .27000000E+01  FOVY   =  .13500000E+01
   ANGX   =  .18000000E+00  ANGY  =  .18000000E+00  LOW    =  .20000000E+01
   LHI    =  .60000000E+02  BIASK = -.60000000E+01  BIASJ  =  .12000000E+02
   CHIT   =  .10000000E+01  FCLD  =  .10000000E+01  PRD    = $$$$$$$$$$$$$
      0.0000       0.0000      39.3701      10.9111      -7.6269      90.0000
   3320.0000     640.0000     492.1260     350.0000     -17.0000       0.0000
      5.7600      11.5200        .1800        .1800     -12.0000      -6.0000
    .84800000E+03 .18000000E-01 .34778734E-01 .38403317E-01
    .27800000E+03 .23000000E+020.              .23000000E+02
    .22600000E+02 .82733813E-01 .30823983E+00 .59306372E-01
    .10132395E+02 .11604338E+03 .49680424E+03
    .46498111E+01 .13893475E+03 .25497812E+03
```

4.2 (U) LOG PLOT SIGNATURE

The signature predicted for these initial conditions is shown in figure 4-1. This figure depicts the spatial intensity distribution of the signature.

The picture consists of a mosaic of 30 by 60 elements. The apparent effective radiance of each element is depicted by a 2 digit number. The first digit represents the characteristic of the logarithm of the radiance multiplied by a scale factor and the second digit the first number of the mantissa.

The value of the radiance is typically less than unity. Therefore, it is multiplied by a scale factor PRD. If the product of the radiance times PRD was 267.5, then its logarithm would be log 10 (267.5) = 2.4273, which when rounded off to the first decimal and multiplied by 10 becomes 24. Thus, the two digit value printed out for this surface intercept would be 24.

The advantage of using logarithms is in obtaining a large dynamic range with the fewest digits. For example, the surface radiances in figure 4.1 are in the twenties while the hot gas values are in the forties. This indicates at a glance that the hot gas is two orders of magnitude more radiant than the surface.

The background radiance values have been suppressed for picture clarity except for the last column and row. This permits determining at a glance what the background level is and if there are any gradients present.

At the bottom of the picture frame are three lines of real numbers which define aspects of the integrated signature in various ways.

The first line gives the components of contrast irradiance which comprise the composite signature. The first number is the total positive contrast

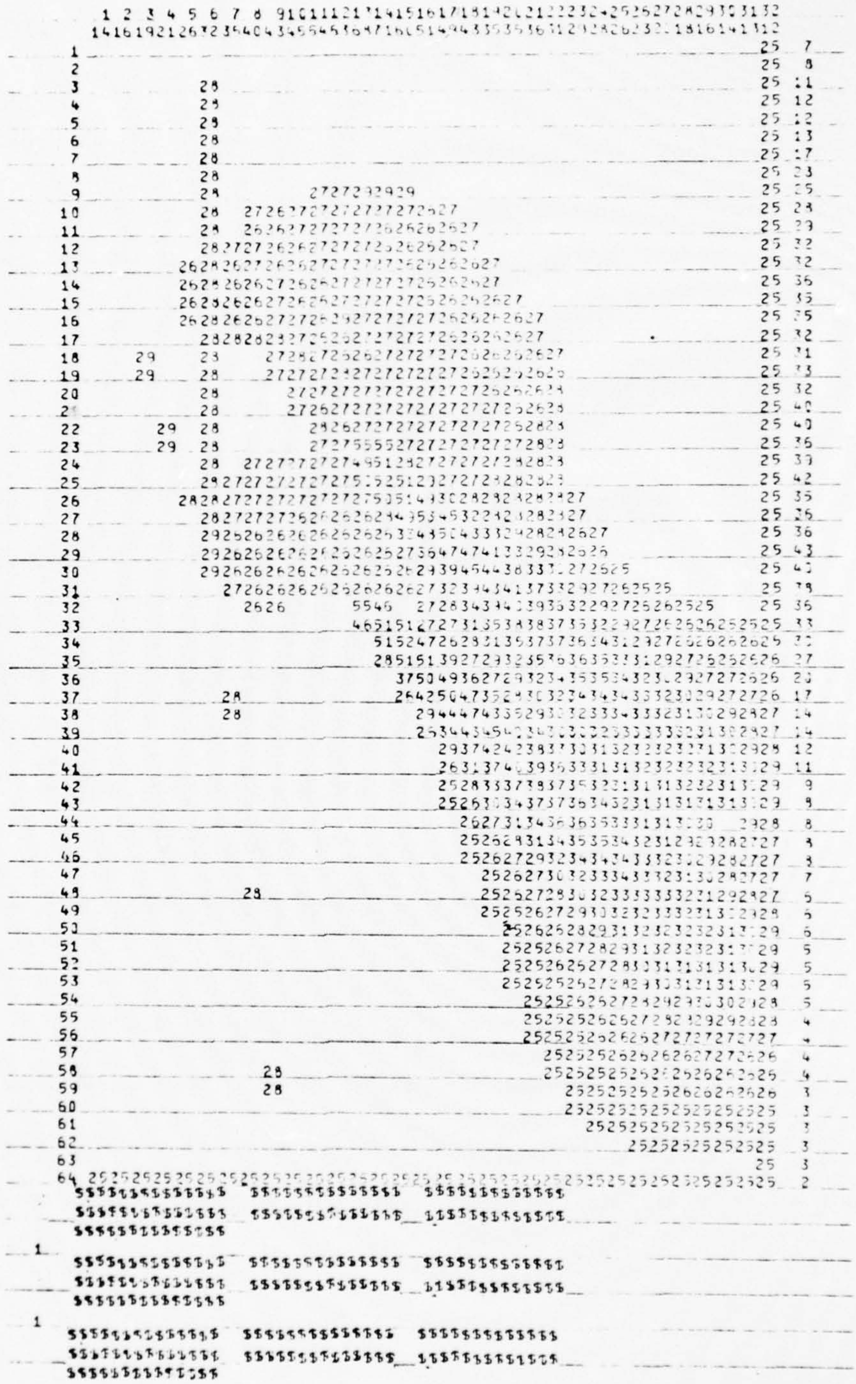


FIGURE 4-1. (U) LOG PLOT SIGNATURE

irradiance, the second number is the total negative contrast irradiance and the third number is the sum of the absolute values of contrast irradiance components.

The second line gives the absolute irradiance values. The first number is the absolute target irradiance, the second number is the absolute irradiance of the background covered by the target, and the third is the contrast irradiance obtained by subtracting the first two numbers.

The third line containing a single number is the apparent effective radiant intensity of the target.

In the above, the irradiance numbers have the standard units, watts/cm^2, the radiant intensity, watts/ster, and the radiant values in the log plot, W/cm^2/ster.

All signature values are weighted for the sensor spectral response.

4.3 (U) SPECTRAL PLOT

The HIDE program also prints out a plot of the spectral radiant intensity of the signature and its composition as shown in figure 4-2.

This plot is in the form of a number pattern wherein the user can connect the numbers and draw the curves.

The identification of the symbols and their priority are listed below. (i.e. If the points on more than one curve fall on the same print location, only one character is printed out over riding the others. Thus, number 1 (C) would predominate over all the others, number 3 (T) would prempt number 4 (R), etc.)

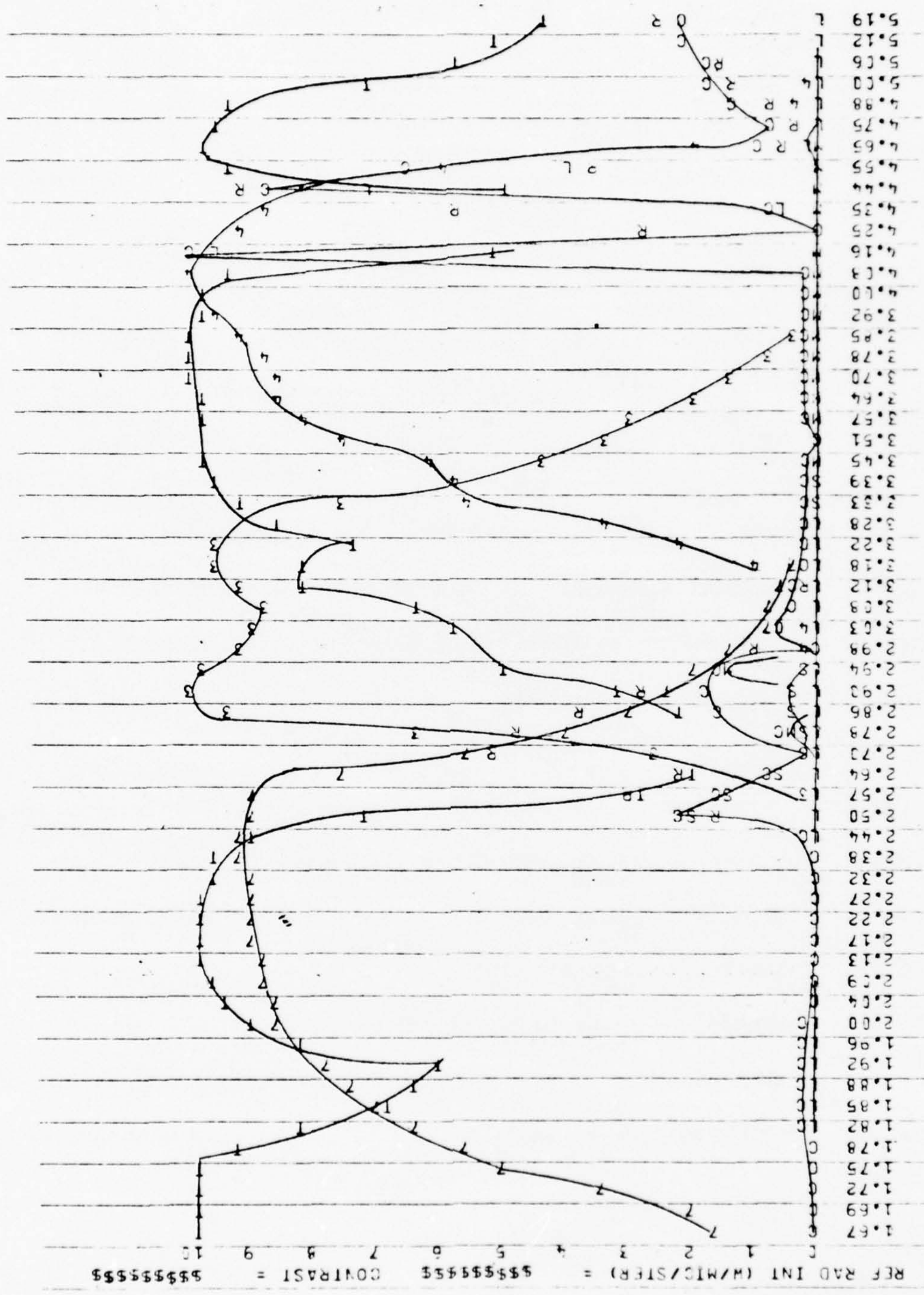


FIGURE 4-2. (U) SPECTRAL PLOT

TABLE 4-2. (U) SPECTRAL PRIORITIES

PRIORITY	SYMBOL	DEFINITION	REFERENCE
1	C	Spectral radiant intensity at receiver	Contrast
2	S,M,L	Effective apparent spectral radiant intensities	Contrast
3	T	Atmospheric transmission	100%
4	R	Spectral radiant intensity	Rad. Int.
5	3,4,7	Detector responses	100%

The vertical coordinate, calibrated from 0 to 10, represents 0 to 100 percent. The horizontal coordinate is calibrated in wavelengths. Each curve is normalized to some reference value which is printed out along the vertical coordinate and specified in Table 4-2.

4.4 (U) BODY INTERCEPT PLOT

A body intercept plot is also printed out as shown in figure 4-3. This is in a mosaic format on a one for one correspondance with the LOG PLOT of the signature. The difference is that the 2 digit numbers given here are the index numbers of the surface elements.

Only body surfaces are shown here, the plume surfaces have been deleted. This plot may be super imposed on the LOG PLOT to investigate the origin of the signature contributions (i.e. tail cone, solar glint from windows, etc.)

```
  1                                                                      1
  2                                                                      2
  3          95                                                          3
  4          95                                                          4
  5          95                                                          5
  6          95                                                          6
  7          95                                                          7
  8          95                                                          8
  9          95          4444464546                                      9
 10          95  5050 2 8 8 2 2 23740                                   10
 11          95  5050 2 2 2 237181818 4                                 11
 12          9573 37351 2 2 218181813 4                                 12
 13        739573 37373 2 2 2 218181818 4                               13
 14        73957373 37347 2 2 2 2181818 4                               14
 15        73957373 37347 2 212 218181818 4                             15
 16        73957878 3 34747 2 2 2 218181818 4                           16
 17          95757575 34545 2 21414181818 4                             17
 18     93   95     375 34545 2 2 2 218181818 4                         18
 19     93   95     3 3 375 1 2 2 2 21818182931                         19
 20          95       3 3 3 1 1 2 216 213292927                         20
 21          95       3666868 1 12222222223127                          21
 22       93 95        686868 1 12222222292727                          22
 23       93 95         3697070 1 122222222727                          23
 24          95  86868686867272 1 1222222232727                         24
 25          958686868686867272 3 1 12223232727                         25
 26        93958686868686868635 3 1 1232323272719                       26
 27          9586868383838383391 3262323232722719                       27
 28          84919191919191919191 32423232327271919                     28
 29          84919191919191919191 32423232327271919                     29
 30          84919191919191919191242323232327271919                     30
 31            929191919191919191919124232323272719 19                  31
 32              9191       6971       32423232327 27                   32
 33                         7171       324232323                        33
 34                                     2424 5                          34
 35                                     2525 5                          35
 36                                       25                            36
 37            94                                                       37
 38            94                                                       38
 39                                                                     39
 40                                                                     40
 41                                                                     41
 42                                                                     42
 43                                                                     43
 44                                                                     44
 45                                                                     45
 46                                                                     46
 47                                                                     47
 48              94                                                     48
 49                                                                     49
 50                                                                     50
 51                                                                     51
 52                                                                     52
 53                                                                     53
 54                                                                     54
 55                                                                     55
 56                                                                     56
 57                                                                     57
 58                94                                                   58
 59                94                                                   59
 60                                                                     60
 61                                                                     61
 62                                                                     62
 63                                                                     63
 64                                                                     64

    1 2 3 4 5 6 7 8 910111213141516171819202122232425262728293031 32
```

FIGURE 4-3. (U) BODY INTERCEPT PLOT

4.5 (U) GREY SCALE PLOT

The HIDE model also generates a grey scale plot of the spatial distribution of intensity of the signature as shown in figure 4-4.

This is based on a 10 level grey scale using symbols to depict the density levels.

This plot enables one to find hot spots quickly and track them through the BODY and LOG PLOTS.

4.6 (U) Grey Shade Plot

Data from the log plot signature is used in an off line program to generate a grey shade plot as shown in figure 4-5. It depicts the same information as the grey scale plot but in a way which provides a truer visualization of the grey shade densities. This effect is obtained by use of an overprint process.

4.7 (U) Grey Shade Photo

This photograph, shown in figure 4-6, is a simulation of what an infrared camera would see when looking at the target. It was obtained by processing the digital signature image mosaic. The special intensity distribution values from the log plot signature were fed through a hybrid computer's D/A converter to convert digital values to analog video amplitudes. The video amplitudes were then displayed on a kinescope and photographed. The capability of generating photographs of this type is an inherent feature of the digital mosaic techniques used in the HIDE model.

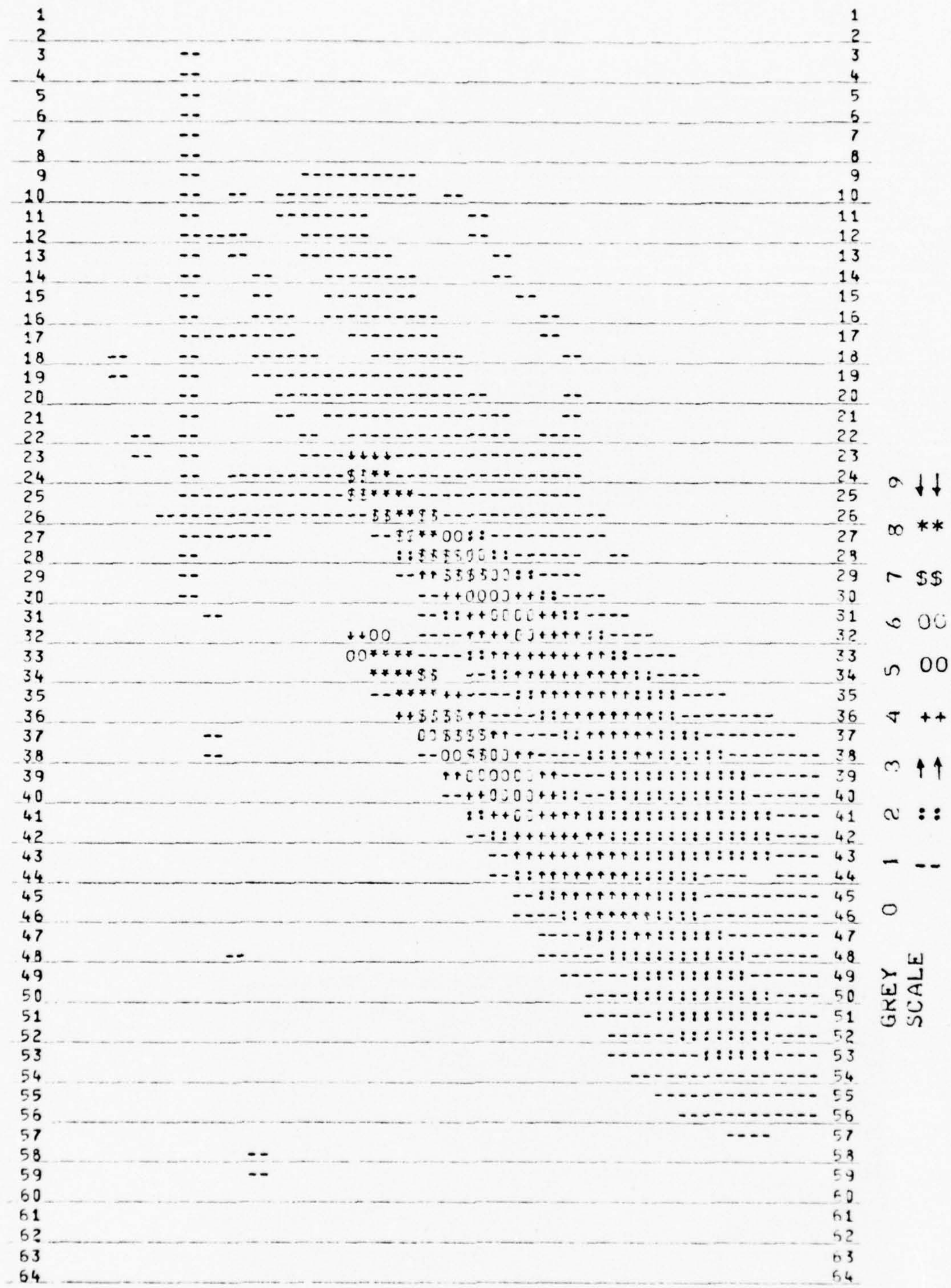


FIGURE 4-4. (U) GREY SCALE PLOT

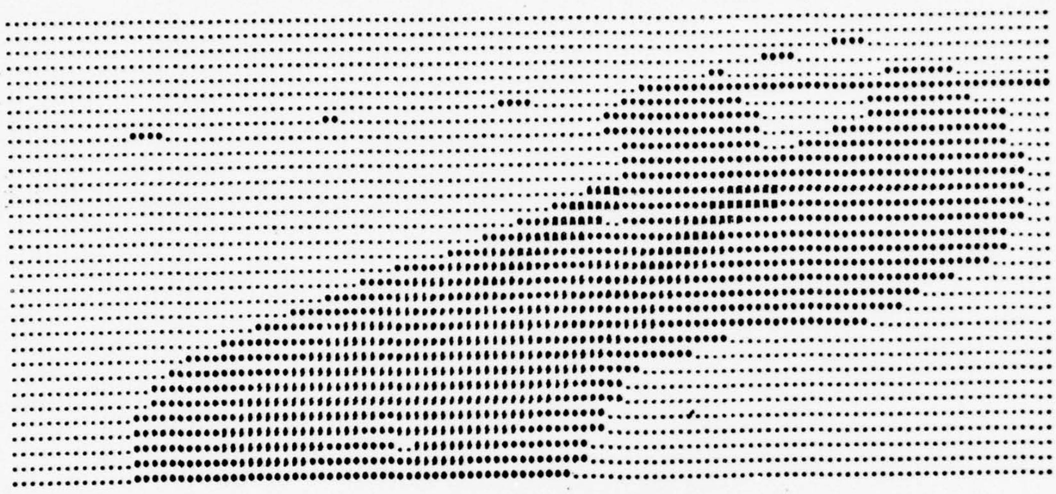


Figure 4-5. Grey Shade Plot

Figure 4-6. Grey Shade Photo

APPENDIX A

BLOCK DATA FOR BODY IN THE HIDE MODEL

```
CHDATA -- PAGE 1     14.25.38     73/09/19

1 -125.000 .000 .000 -40.000 40.000
-357.000 .000 54.000 .000 .000 -90.000 1 1
2 -125.000 .000 .000 -40.000 40.000
-357.000 .000 54.000 .000 .000 90.000 1 1
3 -125.000 .000 .000 -40.000 40.000
-505.500 .000 54.000 .000 .000 .000 1 1
4 -200.000 .000 .000 -74.000 74.000
-282.000 .000 40.000 .000 .000 180.000 1 1
5 -125.000 40.000 40.000 .000 505.500
.001 90.000 14.000 .000 -90.000 .000 4 1
6 -125.000 40.000 -40.000 .000 505.500
90.000 180.000 14.000 .000 -90.000 .000 4 1
7 -140.000 15.000 .000 .000 10.000
.001 360.000 54.010 .000 .000 -90.000 2 3
8 -140.000 15.000 .000 .000 10.000
.001 360.000 54.010 .000 .000 90.000 2 3
9 -220.000 15.000 .000 .000 10.000
.001 360.000 54.010 .000 .000 -90.000 2 3
10 -220.000 15.000 .000 .000 10.000
.001 360.000 54.010 .000 .000 90.000 2 3
11 -300.000 15.000 .000 .000 10.000
.001 360.000 54.010 .000 .000 -90.000 2 3
12 -300.000 15.000 .000 .000 10.000
.001 360.000 54.010 .000 .000 90.000 2 3
13 -380.000 15.000 .000 .000 10.000
.001 360.000 54.010 .000 .000 -90.000 2 3
14 -380.000 15.000 .000 .000 10.000
.001 360.000 54.010 .000 .000 90.000 2 3
15 -460.000 15.000 .000 .000 10.000
.001 360.000 54.010 .000 .000 -90.000 2 3
16 -460.000 15.000 .000 .000 10.000
.001 360.000 54.010 .000 .000 90.000 2 3
17 -200.000 -30.000 71.320 -34.640 .000
-282.000 .000 .000 .000 .000 -60.000 1 1
18 -200.000 -30.000 -71.320 .000 34.640
-282.000 .000 .000 .000 .000 60.000 1 1
19 -200.000 -40.000 54.000 .000 282.000
.001 90.000 20.000 .000 -90.000 .000 4 1
20 -200.000 -40.000 -54.000 .000 282.000
90.000 180.000 20.000 .000 -90.000 .000 4 1
21 -630.500 40.000 .000 -148.500 .000
151.700 180.000 54.000 90.000 90.000 .000 3 1
22 -630.500 40.000 .000 -148.500 .000
180.000 208.300 54.000 90.000 -90.000 .000 3 1
23 -630.500 40.000 .000 -54.000 54.000
.000 83.400 .000 .000 28.300 .000 1 1
24 -630.500 40.000 .000 -40.000 40.000
.000 14.000 .000 .000 -90.000 .000 1 1
25 -630.500 40.000 40.000 .000 14.000
.001 90.000 .000 .000 -90.000 .000 2 1
26 -630.500 40.000 -40.000 .000 14.000
90.000 180.000 .000 .000 -90.000 .000 2 1
27 -756.500 108.000 .000 -308.330 -224.930
166.500 193.500 .000 90.000 .000 28.300 3 1
28 -556.250 .000 54.000 -74.250 .000
```

```
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151.700 180.000 .000 90.000 60.000 .000 3 1
29 -556.250 .000 -54.000 -74.250 .000
180.000 208.300 .000 90.000 -60.000 .000 3 1
30 -556.250 .000 54.000 -77.000 .000
152.530 155.750 .000 90.000 90.000 -15.090 3 1
31 -556.250 .000 -54.000 -77.000 .000
204.250 207.470 .000 90.000 -90.000 -15.090 3 1
32 -482.000 .000 54.000 .000 20.000
60.000 63.420 .000 .000 90.000 .000 3 1
33 -482.000 .000 -54.000 -20.000 .000
116.580 120.000 .000 .000 90.000 .000 3 1
34 -200.000 .000 54.000 .000 20.000
60.000 63.420 .000 .000 90.000 .000 3 1
35 -200.000 .000 -54.000 -20.000 .000
116.580 120.000 .000 .000 90.000 .000 3 1
36 -160.000 .000 54.000 -40.000 .000
180.000 225.000 .000 -90.000 -60.000 .000 3 1
37 -160.000 .000 -54.000 -40.000 .000
135.000 180.000 .000 -90.000 60.000 .000 3 1
38 -206.300 -40.000 77.150 -51.760 -7.060
180.000 217.750 .000 90.000 90.000 26.550 3 1
39 -206.300 -40.000 -77.150 -51.760 -7.060
142.250 180.000 .000 90.000 -90.000 26.550 3 1
40 -52.000 -40.000 .000 -148.000 -108.000
153.500 206.500 .000 -90.000 180.000 .000 3 1
41 -125.000 -40.000 .000 -54.000 54.000
-35.000 .000 .000 .000 .000 180.000 1 1
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.001 360.000 25.000 .000 .000 90.000 4 1
43 -46.500 -15.000 35.000 .000 25.000
.001 360.000 .000 .000 .000 90.000 2 1
44 -46.500 -15.000 -35.000 .000 25.000
.001 360.000 .000 .000 .000 -90.000 2 1
45 -125.000 96.000 54.000 56.000 136.000
.000 30.700 .000 -13.610 .000 -90.000 3 1
46 -125.000 96.000 -54.000 -136.000 -56.000
149.300 180.000 .000 13.610 .000 90.000 3 1
47 -46.500 -40.000 21.000 .000 92.400
.001 180.000 14.000 -13.610 -30.700 .000 4 3
48 -46.500 -40.000 -21.000 .000 92.400
.001 180.000 14.000 13.610 -30.700 .000 4 3
49 -92.700 40.000 32.190 .001 180.000
.001 360.000 14.000 .000 .000 .000 6 3
50 -92.700 40.000 -32.190 .001 180.000
.001 360.000 14.000 .000 .000 .000 6 3
51 54.920 -181.000 .000 -265.900 -173.500
173.080 186.920 .000 -90.000 .000 -59.300 3 3
52 -92.700 40.000 .000 -32.190 32.190
.001 360.000 14.000 .000 .000 90.000 4 1
53 -92.700 40.000 46.200 .000 24.000
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54 -92.700 40.000 -46.200 -24.000 .000
.000 60.000 .000 13.610 59.300 90.000 1 3
55 -46.500 -15.000 35.010 .000 25.000
30.000 60.000 .000 .000 .000 -90.000 2 3
```

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120.000 150.000 .000 .000 .000 90.000 2 3
57 -46.500 -15.000 .000 10.000 35.000
30.000 60.000 25.010 .000 .000 -90.000 4 3
58 -46.500 -15.000 .000 10.000 35.000
30.000 60.000 25.010 -90.000 90.000 .000 4 3
59 -456.000 68.000 47.000 .001 180.000
.001 360.000 8.000 .000 .000 .000 6 1
60 -456.000 68.000 -47.000 .001 180.000
.001 360.000 8.000 .000 .000 .000 6 1
61 -456.000 68.000 47.000 .000 16.000
.001 360.000 8.000 .000 -90.000 .000 4 1
62 -456.000 68.000 -47.000 .000 16.000
.001 360.000 8.000 .000 -90.000 .000 4 1
63 -472.000 68.000 47.000 .000 12.000
.001 360.000 .000 .000 90.000 .000 2 1
64 -472.000 68.000 -47.000 .000 12.000
.001 360.000 .000 .000 90.000 .000 2 1
65 -416.000 68.000 47.000 56.000 70.000
.001 360.000 12.100 .000 -90.000 .000 5 1
66 -416.000 68.000 -47.000 56.000 70.000
.001 360.000 12.100 .000 -90.000 .000 5 1
67 -642.000 68.000 47.000 104.000 156.000
.001 360.000 5.500 .000 90.000 .000 5 1
68 -642.000 68.000 -47.000 104.000 156.000
.001 360.000 5.500 .000 90.000 .000 5 1
69 -387.000 68.000 47.000 130.000 167.000
.001 360.000 3.800 .000 -90.000 .000 5 2
70 -387.000 68.000 -47.000 130.000 167.000
.001 360.000 3.800 .000 -90.000 .000 5 2
71 -554.000 68.000 47.000 .000 11.060
.001 360.000 .000 .000 -90.000 .000 2 1
72 -554.000 68.000 -47.000 .000 11.060
.001 360.000 .000 .000 -90.000 .000 2 1
73 -104.000 40.000 .000 -10.000 50.000
.001 180.000 24.000 .000 .000 .000 4 1
74 -104.000 40.000 .000 .000 24.000
.001 180.000 50.000 .000 .000 .000 2 1
75 -434.000 40.000 -46.000 270.000 337.500
.000 8.350 .000 -90.000 -90.000 11.880 3 1
76 -434.000 40.000 46.000 -337.500 -270.000
171.650 180.000 .000 90.000 -90.000 -11.880 3 1
77 -217.100 72.860 .000 -114.410 -47.590
168.190 191.810 .000 90.000 .000 -8.620 3 1
78 -170.000 40.000 .000 .000 40.000
.001 360.000 10.000 .000 .000 .000 4 1
79 -170.000 40.000 .000 .000 10.000
.001 360.000 40.000 .000 .000 .000 2 1
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.000 372.000 .000 .000 8.000 .000 1 1
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.000 372.000 .000 120.000 -4.000 7.000 1 1
82 -104.000 90.000 .000 -25.000 .000
.000 372.000 .000 -120.000 -4.000 -7.000 1 1
83 -550.000 145.000 .000 -100.000 .000
```

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.001 360.000 20.000 .000 .000 .000 4 1
84 -550.000 145.000 .000 .000 20.000
.001 360.000 .000 .000 .000 .000 2 1
85 .000 45.000 -30.000 -550.000 -440.000
169.710 180.000 .000 -90.000 -90.000 -5.200 3 1
86 .000 45.000 30.000 -550.000 -440.000
180.000 190.290 .000 -90.000 90.000 -5.200 3 1
87 -330.000 105.000 .000 -224.200 -112.100
174.925 185.075 .000 -90.000 .000 -10.290 3 1
88 -440.000 45.000 .000 .000 80.000
.001 360.000 10.000 .000 .000 .000 4 1
89 -440.000 45.000 .000 .000 10.000
.001 360.000 80.000 .000 .000 .000 2 1
90 -630.500 145.000 .000 -83.000 .000
.000 91.000 .000 90.000 90.000 -14.000 1 1
91 -630.500 145.000 .000 -83.000 .000
-91.000 .000 .000 90.000 -90.000 -14.000 1 1
92 -630.500 145.000 .000 -80.500 .000
166.000 194.000 .000 90.000 .000 .000 3 1
93 -550.000 145.000 .000 .000 25.000
.000 372.000 .000 .000 3.400 .000 1 1
94 -550.000 145.000 .000 .000 25.000
.000 372.000 .000 120.000 -1.700 2.940 1 1
95 -550.000 145.000 .000 .000 25.000
.000 372.000 .000 -120.000 -1.700 -2.940 1 1
96 -456.000 68.000 47.000 .000 48.000
.001 360.000 3.000 .000 .000 106.600 4 1
97 -456.000 68.000 -47.000 .000 48.000
.001 360.000 3.000 .000 .000 -106.600 4 1
98 -471.000 68.000 47.000 -48.000 .000
.000 15.300 .000 .000 11.300 10.600 1 1
99 -471.000 68.000 -47.000 .000 48.000
.000 15.300 .000 .000 11.300 -10.600 1 1
A0 -471.000 68.000 47.000 -48.000 .000
.000 15.300 .000 .000 -11.300 10.600 1 1
A1 -471.000 68.000 -47.000 .000 48.000
.000 15.300 .000 .000 -11.300 -10.600 1 1
A2 -104.000 60.000 .000 -10.000 20.000
-446.000 .000 .000 .000 .000 .000 1 1
A3 -104.000 60.000 20.000 .000 6.000
-446.000 .000 .000 .000 .000 -90.000 1 1
A4 -104.000 60.000 -10.000 -6.000 .000
-446.000 .000 .000 .000 .000 90.000 1 1
A5 -486.000 81.000 54.000 .000 41.000
.001 360.000 30.000 .000 .000 150.000 5 1
A6 -486.000 81.000 -54.000 .000 41.000
.001 360.000 30.000 .000 .000 -150.000 5 1
A7 -125.000 40.000 40.000 .001 180.000
.001 300.000 14.000 .000 .000 .000 6 1
A8 -125.000 40.000 -40.000 .001 180.000
.001 300.000 14.000 .000 .000 .000 6 1
A9 -92.700 40.000 32.190 .000 33.200
.001 90.000 14.000 -13.610 -90.000 .000 4 1
B0 -92.700 40.000 -32.190 .000 33.200
90.000 180.000 14.000 13.610 -90.000 .000 4 1
```

```
CHDATA  -- PAGE  5     14.25.38     73/09/19

B1 40.250 54.000 .000 -165.250 -132.950
166.390 193.610 .000 -90.000 .000 .000 3 1
B2 98.200 -40.000 .000 -223.200 -144.700
166.390 193.610 .000 -90.000 .000 .000 3 1

LENGTH =  224 LINES
```

APPENDIX B (U)

TURBINE MODEL FOR

CH-47

HELICOPTER

LISTING AND BLOCK DATA

```
CHTURB  -- PAGE  1     13.31.39     73/09/18

5 PROGRAM CH47(OUTPUT)
6 PRINT,* CH-47 FLIGHT/TURBIN MODEL OPERATING CONDITIONS *
20 INTEGER THROST,HELOGW,HELOW(8)
25 INTEGER WT,TABLE
30*C  THROST = THROTTLE SETTING  (INTERGER)
40*C    1 = MAXIMUM RANGE
50*C    2 = MAXIMUM CRUISE SPEED
60*C    3 = MAXIMUM ENDURANCE
65*C    4 = HOVER
70 THROST=4
75*C  HELOGW = HELICOPTER GROSS WEIGHT, LBS (INTERGER)
80*C  VALUES = 24000,28000,32000,34000,36000,38000,40000
85 WT=4
88 DATA(HELOW(I),I=1,7)/24000,28000,32000,34000,36000,38000,40000/
89 HELOGW=HELOW(WT)
90*C  A = ALTITUDE, FEET (REAL)
100  A=2000.
110*C TEMP = AMBIENT AIR TEMPERATURE, DEG CENTIGRADE (REAL)
120 TEMP=15.
130 DIMENSION HEIGHT( 13)
160 DIMENSION V1T4(13),V2T4(12),V3T4(11),V4T4(10),V5T4(9),V6T4(8),
170+ALT(4)
180 DIMENSION Q1T1(11),Q2T1(10),Q3T1(9),Q4T1(8),Q5T1(7),Q6T1(6),
190+Q7T1(5),Q8T1(4)
200 DIMENSION Q1T2(11),Q2T2(10),Q3T2(9),Q4T2(8),Q5T2(7),Q6T2(6),
210+Q7T2(5),Q8T2(4)
220 DIMENSION Q1T3(11),Q2T3(10),Q3T3(9),Q4T3(8),Q5T3(7),Q6T3(6),
230+Q7T3(5),Q8T3(4)
240 DIMENSION Q1T4(13),Q2T4(12)
242 DIMENSION Q3T4(11),Q4T4(10),Q5T4(9),Q6T4(8),
250+Q7T4(8),Q8T4(7)
260 DIMENSION V1T1(11),V2T1(10),V3T1(9),V4T1(8),V5T1(7),V6T1(6),
270+V7T1(5),V8T1(4)
280 DIMENSION V1T2(11),V2T2(10),V3T2(9),V4T2(8),V5T2(7),V6T2(6),
290+V7T2(5),V8T2(4)
300 DIMENSION V1T3(11),V2T3(10),V3T3(9),V4T3(8),V5T3(7),V6T3(6),
310+V7T3(5),V8T3(4),
320+V7T4(8),V8T4(7)
330 DIMENSION OAT0(3),OAT4(3),OAT8(3),OAT12(3)
340 DIMENSION GW(3)
350 DIMENSION VEL(10),PITCH(10)
360 DIMENSION S0(5),W1(5),W2(5),W3(5),W4(5),W5(5)
370 DIMENSION U1(5),U2(5),U3(5),U4(5),U5(5)
380 DIMENSION W9(5),U9(5)
390 DIMENSION F1(5)
400 DIMENSION A0(5),T0(5),D1(5)
410 DIMENSION T2(9),C1(9),C2(9),C3(9)
420 DIMENSION R1(7),R2(7)
430 REAL L1( 5)
440 REAL M1,M2,L
450 DATA (VEL(I4),I4=1,10)/0.,10.,20.,30.,40.,50.,60.,70.,80.,90./
460 DATA (PITCH(I4),I4=1,10)/.45,.20,-.25,-.90,-1.7,-2.5,-3.7,-5.05,
470+-6.35,-8./
540 DATA (S0(I1),I1=1,5)/500.,1000.,1500.,2000.,2500./
550 DATA (W1(I1),I1=1,5)/14.3,16.5,17.7,20.,21.5/
```

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CHTURB  -- PAGE  2    13.31.39    73/09/18

560 DATA (W2(I1),I1=1,5)/12.6,14.6,16.75,17.3,18.8/
570 DATA (W3(I1),I1=1,5)/11.1,12.9,14.55,15.75,16.4/
580 DATA (W4(I1),I1=1,5)/9.7,11.5,13.,13.8,13.7/
590 DATA (W5(I1),I1=1,3)/8.8,10.2,11.3/
600 DATA (U1(I2),I2=1,5)/560.,810.,1020.,1240.,1460./
610 DATA (U2(I2),I2=1,5)/510.,750.,985.,1200.,1450./
620 DATA (U3(I2),I2=1,5)/470.,700.,920.,1160.,1400./
630 DATA (U4(I2),I2=1,5)/415.,650.,880.,1120.,1300./
640 DATA (U5(I2),I2=1,3)/380.,600.,840./
650 DATA (F1(I3),I3=1,5)/75.,100.,130.,165.,200./
660 DATA (A0(I4),I4=1,5)/0.,5000.,10000.,15000.,20000./
670 DATA (T0(I4),I4=1,5)/519.,501.,483.,465.,447./
680 DATA (D1(I4),I4=1,5)/.00238,.00205,.001755,.001493,.0012681 /
690 DATA (L1(I4),I4=1,5)/1.000,.832,.688,.564,.460/
700 DATA (T2(I5),I5=1,9)/420.,440.,460.,480.,500.,520.,540.,560.,580/
710 DATA (C1(I5),I5=1,9)/.26,.215,.16,.108,.053,.0,-.058,-.11,-.162/
720 DATA (C2(I5),I5=1,9)/.36,.295,.215,.148,.065,
725+-.005,-.07,-.135,-.2/
730 DATA (C3(I5),I5=1,9)/80.,60.,35.,25.,10.,0.,-12.,-25.,-40./
740 DATA (R1(I6),I6=1,7)/1000.,1500.,2000.,2500.,3000.,3500.,4000./
750 DATA (R2(I6),I6=1,7)/1360.,1425.,1505.,1595.,1700.,1805.,1940./
760 DATA G/32.2/
770 DATA H/.24/
780 DATA E/778./
790 DATA(HEIGHT(K1),K1=1,9)/0.,2000.,4000.,6000.,8000.,10000.,
800+12000.,14000.,15000. /
810 DATA(Q5T4(K1),K1=1,4)/729.,746.,765.,786./
830 DATA(Q6T4(K1),K1=1,2)/786.,805./
840 DATA(Q7T4(K1),K1=1,1)/845./
860 DATA(Q1T2(K1),K1=1,9)/753.,720.,689.,658.,617.,
870+555.,486.,427.,390./
880 DATA(V2T2(K1),K1=1,9)/152.,152.,151.,149.,147.,145.,137.,
890+125.,118./
900 DATA(Q2T2(K1),K1=1,9)/753.,720.,689.,658.,631.,603.,538.,
910+489.,462./
920 DATA(V3T2(K1),K1=1,9)/149.,148.,146.,143.,140.,135.,127.,
930+103.,88./
940 DATA(Q3T2(K1),K1=1,9)/753.,720.,689.,658.,631.,603.,575.,
950+496.,470./
960 DATA(V4T2(K1),K1=1,7)/148.,146.,143.,140.,134.,127.,104./
970 DATA(Q4T2(K1),K1=1,7)/753.,720.,689.,658.,631.,603.,505./
980 DATA(V5T2(K1),K1=1,7)/145.,143.,140.,135.,127.,115.,89./
990 DATA(Q5T2(K1),K1=1,7)/753.,720.,689.,658.,631.,603.,522./
1000 DATA(V6T2(K1),K1=1,6)/143.,139.,134.,128.,118.,101./
1010 DATA(Q6T2(K1),K1=1,6)/753.,720.,689.,658.,631.,603./
1020 DATA(V7T2(K1),K1=1,5)/125.,122.,113.,100.,87./
1030 DATA(Q7T2(K1),K1=1,5)/653.,629.,599.,527.,568./
1080 DATA(Q1T4(K1),K1=1,8)/441.,441.,443.,449.,457.,466.,477.,488./
1120 DATA(Q2T4(K1),K1=1,8)/522.,530.,540.,559.,563.,577.,592.,610./
1160 DATA(Q3T4(K1),K1=1,6)/621.,634.,648.,663.,680.,700./
1190 DATA(Q4T4(K1),K1=1,5)/674.,689.,705.,723.,744./
1250 DATA (V1T1(K1),K1=1,9)/140.,140.,139.,139.,139.,138.,137.,
1260+125.,118./
1270 DATA(Q1T1(K1),K1=1,9)/606.,579.,555.,538.,515.,499.,486.,
1280+427.,390./
```

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```
 DATA(V2T1(K1),K1=1,9)/142.,142.,141.,141.,140.,138.,136.,
+125.,118./
 DATA(Q2T1(K1),K1=1,9)/661.,624.,606.,585.,566.,555.,546.,
+489.,461./
 DATA(V3T1(K1),K1=1,9)/143.,143.,142.,141.,138.,135.,127.,
+103.,88./
 DATA(Q3T1(K1),K1=1,9)/687.,678.,658.,635.,
+621.,604.,575.,496.,470./
 DATA(V4T1(K1),K1=1,7)/143.,143.,141.,139.,134.,127.,104./
 DATA(Q4T1(K1),K1=1,7)/711.,686.,678.,659.,631.,603.,505./
 DATA(V5T1(K1),K1=1,7)/143.,142.,140.,135.,127.,115.,89./
 DATA(Q5T1(K1),K1=1,7)/734.,709.,689.,658.,631.,603.,522./
 DATA(V6T1(K1),K1=1,6)/144.,136.,127.,115.,103.,83./
 DATA(Q6T1(K1),K1=1,6)/753.,720.,689.,658.,631.,603./
 DATA(V7T1(K1),K1=1,5)/125.,122.,113.,100.,87./
 DATA(Q7T1(K1),K1=1,5)/653.,628.,599.,527.,568./
 DATA(V1T2(K1),K1=1,9)/154.,154.,154.,153.,151.,146.,137.,
+125.,118./
 DATA(V1T3(K1),K1=1,9)/69.,72.,74.,76.,77.,78.,79.,80.,80./
 DATA(Q1T3(K1),K1=1,9)/312.,311.,311.,312.,312.,313.,314.,
+316.,318./
 DATA(V2T3(K1),K1=1,9)/75.,77.,78.,79.,80.,81.,81.,82.,82./
 DATA(Q2T3(K1),K1=1,9)/361.,361.,361.,361.,362.,365.,370.,
+377.,383./
 DATA(V3T3(K1),K1=1,9)/78.,80.,80.,81.,82.,82.,82.,82.,82./
 DATA(Q3T3(K1),K1=1,9)/409.,410.,413.,413.,418.,426.,441.,
+467.,483./
 DATA(V4T3(K1),K1=1,7)/80.,81.,81.,82.,82.,82.,82./
 DATA(Q4T3(K1),K1=1,7)/434.,435.,437.,441.,451.,465.,491./
 DATA(V5T3(K1),K1=1,7)/[illegible]1.,81.,82.,83.,83.,83.,82./
 DATA(Q5T3(K1),K1=1,7)/459.,461.,465.,474.,489.,515.,550./
 DATA(V6T3(K1),K1=1,6)/82.,82.,83.,83.,83.,83./
 DATA(Q6T3(K1),K1=1,6)/485.,489.,497.,511.,536.,572./
 DATA(V7T3(K1),K1=1,5)/82.,83.,83.,83.,83./
 DATA(Q7T3(K1),K1=1,5)/513.,520.,534.,557.,592./
  DATA PI/3.1415926535/
  DATA DTR/0.0174532925/
  DATA CHORD/2.1416/
  DATA BLADES/3./
  DATA RADIUS/30./
  DATA ROTSPD/4./
  DATA DRAG/0.0083/
  DATA PWREFF/0.90/
  DATA TILT/6.5/
 T = 15. - 2.*A/1000.
 D=TEMP-T
 B=-(D+25.)*D*(D-10.)*(D-30.)*(D-40.)/15./40./50./70./80.
 B=B*3.28571
 B=B+(D+40.)*D*(D-10.)*(D-30.)*(D-40.)/15./25./35./55./65.*2.
 B=B-(D+40.)*(D+25.)*D*(D-30.)*(D-40.)/50./35./10./20./30.
 B=B+(D+40.)*(D+25.)*D*(D-10.)*(D-40.)/70./55./30./20./10.*2.7149
 DELP=B-(D+40.)*(D+25.)*D*(D-10.)*(D-30.)/80./65./40./30./10.*3.[illegible]
 A = A + 1000.*DELP
 T = TEMP*9./5.+492.
 TABLE = (THROST-1 )*7  + WT
```

```
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GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,
+21,22,23,24,25,26,27,28),TABLE
1 CALL CONFRA( 9,HEIGHT,V1T1,A,V)
CALL CONFRA( 9,HEIGHT,Q1T1,A,Q)
GO TO 199
2 CALL CONFRA( 9,HEIGHT,V2T1,A,V)
CALL CONFRA( 9,HEIGHT,Q2T1,A,Q)
GO TO 199
3 CALL CONFRA( 9,HEIGHT,V3T1,A,V)
CALL CONFRA( 9,HEIGHT,Q3T1,A,Q)
GO TO 199
4 CALL CONFRA( 7,HEIGHT,V4T1,A,V)
CALL CONFRA( 7,HEIGHT,Q4T1,A,Q)
GO TO 199
5 CALL CONFRA( 7,HEIGHT,V5T1,A,V)
CALL CONFRA(7,HEIGHT,Q5T1,A,Q)
GO TO 199
6 CALL CONFRA( 6,HEIGHT,V6T1,A,V)
CALL CONFRA( 6,HEIGHT,Q6T1,A,Q)
GO TO 199
7 CALL CONFRA( 5,HEIGHT,V7T1,A,V)
CALL CONFRA( 5,HEIGHT,Q7T1,A,Q)
GO TO 199
8 CALL CONFRA( 9,HEIGHT,V1T2,A,V)
CALL CONFRA( 9,HEIGHT,Q1T2,A,Q)
GO TO 199
9 CALL CONFRA( 9,HEIGHT,V2T2,A,V)
CALL CONFRA( 9,HEIGHT,Q2T2,A,Q)
GO TO 199
10 CALL CONFRA( 9,HEIGHT,V3T2,A,V)
CALL CONFRA( 9,HEIGHT,Q3T2,A,Q)
GO TO 199
11 CALL CONFRA( 7,HEIGHT,V4T2,A,V)
CALL CONFRA( 7,HEIGHT,Q4T2,A,Q)
GO TO 199
12 CALL CONFRA( 7,HEIGHT,V5T2,A,V)
CALL CONFRA( 7,HEIGHT,Q5T2,A,Q)
GO TO 199
13 CALL CONFRA( 6,HEIGHT,V6T2,A,V)
CALL CONFRA(6,HEIGHT,Q6T2,A,Q)
GO TO 199
14 CALL CONFRA( 5,HEIGHT,V7T2,A,V)
CALL CONFRA( 5,HEIGHT,Q7T2,A,Q)
GO TO 199
15 CALL CONFRA( 9,HEIGHT,V1T3,A,V)
CALL CONFRA( 9,HEIGHT,Q1T3,A,Q)
GO TO 199
16 CALL CONFRA( 9,HEIGHT,V2T3,A,V)
CALL CONFRA( 9,HEIGHT,Q2T3,A,Q)
GO TO 199
17 CALL CONFRA( 9,HEIGHT,V3T3,A,V)
CALL CONFRA( 9,HEIGHT,Q3T3,A,Q)
GO TO 199
18 CALL CONFRA( 7,HEIGHT,V4T3,A,V)
CALL CONFRA( 7,HEIGHT,Q4T3,A,Q)
```

```
CHTURB  -- PAGE  5    13.31.39    73/09/18

2380 GO TO 199
2390 19 CALL CONFRA( 7,HEIGHT,V5T3,A,V)
2400 CALL CONFRA( 7,HEIGHT,Q5T3,A,Q)
2410 GO TO 199
2420 20 CALL CONFRA( 6,HEIGHT,V6T3,A,V)
2430 CALL CONFRA( 6,HEIGHT,Q6T3,A,Q)
2440 GO TO 199
2450 21 CALL CONFRA( 5,HEIGHT,V7T3,A,V)
2460 CALL CONFRA( 5,HEIGHT,Q7T3,A,Q)
2470 GO TO 199
2480 22 V=0.
2490 CALL CONFRA( 8,HEIGHT,Q1T4,A,Q)
2500 GO TO 199
2510 23 V=0.
2520 CALL CONFRA( 8,HEIGHT,Q2T4,A,Q)
2530 GO TO 199
2540 24 V=0.
2550 CALL CONFRA( 6,HEIGHT,Q3T4,A,Q)
2560 GO TO 199
2570 25 V=0.
2580 CALL CONFRA( 5,HEIGHT,Q4T4,A,Q)
2590 GO TO 199
2600 26 V=0.
2610 CALL CONFRA( 4,HEIGHT,Q5T4,A,Q)
2620 GO TO 199
2630 27 V=0.
2640 CALL CONFRA( 2,HEIGHT,Q6T4,A,Q)
2650 GO TO 199
2660 28 V=0.
2670 Q=845.
2680 GO TO 199
2800 199 CONTINUE
2810 A = A - 1000.*DELP
2820 OTP = Q
2830 TC= 5./9.*(T-492.)
2840 S=2.88*OTP
2850 CALL CONFRA(10,VEL,PITCH,V,BETA)
2860  ALPHA = (BETA - TILT)*DTR
2870 V0=V*1.67
2880 HEL = HELOGW
2882 CALL CONFRA(5,A0,T0,A,T1)
2884 CALL CONFRA(5,A0,D1,A,D)
2886 CALL CONFRA(5,A0,L1,A,L)
2890  SIGMAE = CHORD*BLADES/(PI*RADIUS)
2892  SPDRTO = V0*COS(ALPHA)/(2.*PI*ROTSPD*RADIUS)
2894  PWREQ = PI**4*D*ROTSPD**3*RADIUS**5*DRAG
2896  PWREQ = PWREQ*SIGMAE*(1.+SPDRTO**2)
2898  PWRAVL = PWREFF*550.*S
2900  VIN = (PWRAVL - PWREQ)*COS(ALPHA)/HEL + V0*SIN(ALPHA)
2910 IF (VIN.LT.0.) VIN=.01
2920 CALL CONFRA(5,S0,W1,S,W9(1))
2930 CALL CONFRA(5,S0,W2,S,W9(2))
2940 CALL CONFRA(5,S0,W3,S,W9(3))
2950 CALL CONFRA(5,S0,W4,S,W9(4))
2960 CALL CONFRA(3,S0,W5,S,W9(5))
```

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```
CALL CONFRA(5,S0,U1,S,U9(1))
CALL CONFRA(5,S0,U2,S,U9(2))
CALL CONFRA(5,S0,U3,S,U9(3))
CALL CONFRA(5,S0,U4,S,U9(4))
CALL CONFRA(3,S0,U5,S,U9(5))
CALL CONFRA(5,S0,F1,S,F9)
CALL CONFRA(5,A0,W9,A,W8)
CALL CONFRA(5,A0,U9,A,U8)
F8=F9
D2=D*T1/T
M1=T1/519.
M2=SQRT(M1)
CALL CONFRA(9,T2,C1,T1,C4)
CALL CONFRA(9,T2,C2,T1,C5)
CALL CONFRA(9,T2,C3,T1,C6)
CALL CONFRA(9,T2,C1,T,C7)
CALL CONFRA(9,T2,C2,T,C8)
CALL CONFRA(9,T2,C3,T,C9)
R3=S/(L*M2)
CALL CONFRA(6,R1,R2,R3,R4)
R5=R4*T/519.
W6 = W8*(1.+(C7-C4)/(1.+C4))
U6 = U8*(1.+(C8-C5)/(1.+C5))
F5=F8-(W8*V0)/G
F6 = F5+(L*C9-W8*(1.+C7)*V0/G)-(L*C6-W8*(1.+C4)*V0/G)
Q1=1.+U6/(W6*3600.)
V7=(G*F6/W6+2.*V0)/Q1
T7 = R5-V7**2/(2.*G*H*E)
A7=(W6*T7*Q1)/(G*D2*V7)
D7=24.*SQRT(A7/3.1416)
PRINT 222, A, T, THROST,HELOGW
222 FORMAT(//*ALTITUDE(FT) = *,F12.4/
+* AMBIENT TEMPERATURE (R) = *,F12.4/
+* THROTTLE SETTING = *,I4/
+* GROSS WEIGHT (LBS) = *,I10)
PRINT 225, V, S, V7, T7, D7, Q1, BETA, VIN
225 FORMAT(//* VELOCITY (KNOTS) IAS = *,F12.4/
+* SHP = *,F12.4/
+* EXIT VELOSITY (FT/SEC) = *,F12.4/
+* EXIT TEMPERATURE (R) = *,F12.4/
+* EXIT DIAMETER (INCHES) = *,F12.4/
+* 1 + FUEL/AIR RATIO = *,F12.4/
+* HELICOPTER PITCH (DEG) = *,F12.4/
+* DOWN WASH VELOSITY (FT/SEC) = *,F12.4)
END
*C   PHILLIPS INTERPOLATION RUTINE
*C
*C
SUBROUTINE CONFRA(N,X,Y,XI,YI)
DIMENSION X(1),Y(1)
IF(XI.LT.X(1))GO TO 100
IF(XI.GT.X(N))GO TO 110
DO 10 I=2,N
II=I
IF(XI.LT.X(I))GO TO 20
```

```
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10 CONTINUE
20 I2=II+1
I1=II
I0=II-1
NN=N+1
IF(I2.NE.NN)GO TO 40
I2=II
I1=II-1
I0=II-2
40 A1=(XI-X(I1))*(XI-X(I2))/((X(I0)-X(I1))*(X(I0)-X(I2)))
A2=(XI-X(I0))*(XI-X(I2))/((X(I1)-X(I0))*(X(I1)-X(I2)))
A3=(XI-X(I0))*(XI-X(I1))/((X(I2)-X(I0))*(X(I2)-X(I1)))
YI=A1*Y(I0)+A2*Y(I1)+A3*Y(I2)
GO TO 1000
100 I2=1
I1=2
I0=3
GO TO 120
110 I2=N
I1=N-1
I0=N-2
120 A=(X(I0)-X(I2))
Y2P=(Y(I2)-Y(I1))/(X(I2)-X(I1))
A=A*A
B=(X(I1)-X(I2))
B=B*B
C=X(I0)-X(I1)
DEN=A*B*C
D1=(Y(I0)-Y2P*(X(I0)-X(I2))-Y(I2))*B
D2=(Y(I1)-Y2P*(X(I1)-X(I2))-Y(I2))*A
AA=(D1-D2)/DEN
D1=D1*B
D2=D2*A
BB=(D2-D1)/DEN
A=XI-X(I2)
A=A*A*A
B=XI-X(I2)
B=B*B
YI=AA*A+BB*B+Y2P*(XI-X(I2))+Y(I2)
1000 GO TO 1500
*C  TO PRINT OUT INTERPOLATIONS CHANGE STATMENT 1000 TO CONTINUE
PRINT 1010,XI,YI
PRINT 1020,(X(I),I=1,N)
PRINT 1020,(Y(I),I=1,N)
1010 FORMAT(//*X=*F10.4,*Y=*F10.4)
1020 FORMAT(9F8.3)
1500 CONTINUE
RETURN
END

LENGTH =  379 LINES
```

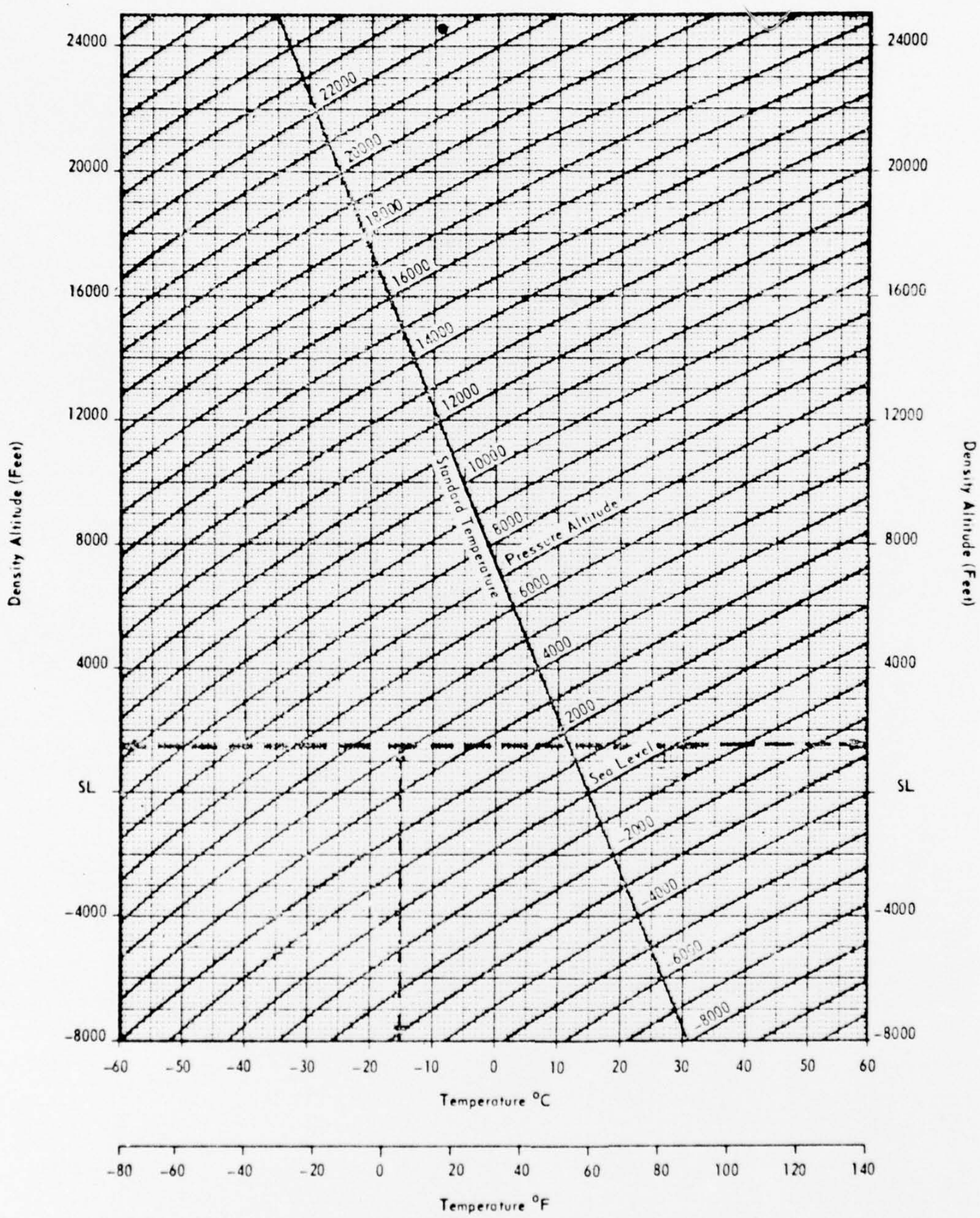
APPENDIX C (U)

SELECTED DATA

FROM THE

CH-47

OPERATOR'S MANUAL



Density Altitude (Feet)
24000
20000
16000
12000
8000
4000
SL
-4000
-8000
22000
20000
18000
16000
14000
12000
10000
8000
Pressure Altitude
6000
4000
2000
Sea Level
-2000
-4000
-6000
-8000
Standard Temperature
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
Temperature °C
-80 -60 -40 -20 0 20 40 60 80 100 120 140
Temperature °F

MODEL(S): CH-47B
ENGINE(S): (2) T55-L-7B

BEST RANGE SPEED

STANDARD DAY

CONFIGURATION: Clean

GROSS WEIGHT	ALT	OPERATING INSTRUCTIONS Rotor Speed	Approximate Tor/Eng	Approximate Fuel Flow	Speed/Knots TAS	Speed/Knots IAS
Pounds	Feet	Rpm	Lb-Ft	Total lb/hr	TAS	IAS
32000 to 28001	15000	230	470	1730	88+	63+
	14000	230	496	1825	103+	78+
	12000	230	575	2095	127*	104*
	10000	230	604	2215	135	114
	8000	230	621	2295	138	122
	6000	230	635	2390	141	129
	4000	230	658	2505	142	134
	2000	230	678	2620	143	139
	SL	230	687	2720	143	144
28000 to 24001	15000	230	451	1710	118+	90+
	14000	230	489	1805	125+	98+
	12000	230	546	2000	136	111
	10000	230	555	2075	138	119
	8000	230	566	2155	140	124
	6000	230	585	2255	141	129
	4000	230	606	2375	141	133
	2000	230	624	2480	142	139
	SL	230	661	2590	142	143
24000 to 20000	15000	230	390	1515	118+	90+
	14000	230	427	1630	125+	98+
	12000	230	486	1845	137	112
	10000	230	499	1930	138	119
	8000	230	515	2020	139	122
	6000	230	538	2120	139	127
	4000	230	555	2240	139	131
	2000	230	579	2360	140	136
	SL	230	606	2500	140	141

GROSS WEIGHT	ALT	OPERATING INSTRUCTIONS Rotor Speed	Approximate Tor/Eng	Approximate Fuel Flow	Speed/Knots TAS	Speed/Knots IAS
Pounds	Feet	Rpm	Lb-Ft	Total lb/hr	TAS	IAS
40000 to 28001	8000	230	568	2160	87+	72+
	6000	230	527	2100	100+	87+
	4000	230	599	2360	113+	105+
	2000	230	628	2490	122+	117+
	SL	230	653	2620	125+	125+
38000 to 36001	10000	230	603	2215	101+	83+
	8000	230	631	2330	118*	103*
	6000	230	658	2460	128*	115*
	4000	230	689	2600	134*	127*
	2000	230*	720	2740	139*	136*
	SL	230	753	2900	143*	144*
36000 to 34001	12000	230	522	1940	89+	68+
	10000	230	603	2215	115*	96*
	8000	230	631	2330	127*	111*
	6000	230	658	2460	135*	123*
	4000	230	689	2600	140*	132*
	2000	230	709	2720	142	139
	SL	230	734	2840	143	144
34000 to 32001	12000	230	505	1890	104+	82+
	10000	230	603	2215	127*	108*
	8000	230	631	2330	134*	118*
	6000	230	659	2460	139	127
	4000	230	678	2560	141	133
	2000	230	636	2660	143	139
	SL	230	711	2780	143	144

REMARKS:
1. No allowances have been made for fuel reserves.
2. +Airspeed limit.
3. *Airspeed limited by normal power available.
4. When operating at nonstandard conditions, read altitude as density altitude when airspeed limited and read altitude as pressure altitude for range when not airspeed limited.

DATA AS OF: August 1967

DATA BASIS: Flight Test

FUEL GRADE: JP-4

FUEL DENSITY: 6.5 Lb Gal

MODEL(S): CH-47B
ENGINE(S): (2) T55-L-7B

MAXIMUM CRUISE SPEED

STANDARD DAY

CONFIGURATION: Clean

GROSS WEIGHT	ALT	OPERATING INSTRUCTIONS				
		Rotor Speed	Approximate		Speed/Knots	
			Tor/Eng	Fuel Flow		
Pounds	Feet	Rpm	Lb-Ft	Total lb/hr	TAS	IAS
32000 to 28001						
	15000	230	470	1730	88*	63*
	14000	230	496	1825	103*	78*
	12000	230	575	2095	127	104
	10000	230	603	2215	135	114
	8000	230	631	2330	140	124
	6000	230	658	2460	143	131
	4000	230	689	2600	146	138
	2000	230	720	2740	148	145
	SL	230	753	2900	149	151
28000 to 24001						
	15000	230	462	1710	118*	90*
	14000	230	489	1805	125*	98*
	12000	230	538	1985	137*	112*
	10000	230	603	2215	145	124
	8000	230	631	2330	147	130
	6000	230	658	2460	149	137
	4000	230	689	2600	151	143
	2000	230	720	2740	152	149
	SL	230	753	2900	152	154
24000 to 20000						
	15000	230	390	1515	118*	90*
	14000	230	427	1630	125*	98*
	12000	230	486	1845	137*	112*
	10000	230	555	2080	146*	127*
	8000	230	617	2290	151*	134*
	6000	230	658	2460	153	141
	4000	230	689	2600	154	147
	2000	230	720	2740	154	151
	SL	230	753	2900	154	156

GROSS WEIGHT	ALT	OPERATING INSTRUCTIONS				
		Rotor Speed	Approximate		Speed/Knots	
			Tor/Eng	Fuel Flow		
Pounds	Feet	Rpm	Lb-Ft	Total lb/hr	TAS	IAS
40000 to 38001						
	8000	230	568	2160	87*	72*
	6000	230	527	2100	100*	87*
	4000	230	599	2360	113*	105*
	2000	230	629	2490	122*	117*
	SL	230	653	2620	125*	125*
38000 to 36001						
	10000	230	603	2215	101*	83*
	8000	230	631	2330	118	103
	6000	230	658	2460	128	115
	4000	230	689	2600	134	127
	2000	230	720	2740	139	136
	SL	230	753	2900	143	144
36000 to 34001						
	12000	230	522	1940	89*	68*
	10000	230	603	2215	115	96
	8000	230	631	2330	127	111
	6000	230	658	2460	135	123
	4000	230	689	2600	140	132
	2000	230	720	2740	143	144
	SL	230	753	2900	145	147
34000 to 32001						
	12000	230	505	1890	104*	82*
	10000	230	603	2215	127	108
	8000	230	631	2330	134	118
	6000	230	658	2460	140	127
	4000	230	689	2600	143	136
	2000	230	720	2740	146	143
	SL	230	753	2900	148	149

REMARKS:
1. No allowances have been made for fuel reserves.
2. *Airspeed limit.
3. All airspeeds limited by normal power available except where noted.
4. When operating at nonstandard conditions, read altitude as density altitude when airspeed limited and read altitude as pressure altitude for range when not airspeed limited.

DATA AS OF: August 1967
DATA BASIS: Flight Test

FUEL GRADE: JP-4
FUEL DENSITY: 6.5 Lb/Gal

MODEL(S): CH-47B
ENGINE(S): (2) T55-L-7B

MAXIMUM ENDURANCE
STANDARD DAY

CONFIGURATION: Clean

GROSS WEIGHT	ALT	OPERATING INSTRUCTIONS Rotor Speed	Approximate Tor/Eng	Approximate Fuel Flow	Speed/Knots	
Pounds	Feet	Rpm	Lb-Ft	Total lb/hr	TAS	IAS
32000 to 28001	15000	230	483	1767	82	59
	14000	230	467	1736	82	60
	12000	230	441	1703	82	62
	10000	230	426	1709	82	65
	8000	230	418	1742	82	67
	6000	230	413	1792	81	69
	4000	230	410	1850	80	70
	2000	230	410	1919	80	72
	SL	230	409	1994	78	73
28000 to 24001	15000	230	383	1481	82	58
	14000	230	377	1485	82	50
	12000	230	370	1513	81	62
	10000	230	365	1554	81	64
	8000	230	362	1604	80	65
	6000	230	361	1663	79	67
	4000	230	361	1728	78	68
	2000	230	361	1800	77	69
	SL	.230	361	1876	75	69
24000 to 20000	15000	230	318	1310	80	57
	14000	230	316	1329	80	58
	12000	230	314	1373	79	60
	10000	230	313	1424	78	61
	8000	230	312	1479	77	62
	6000	230	312	1542	76	63
	4000	230	311	1608	74	64
	2000	230	311	1679	72	64
	SL	230	312	1759	69	63

GROSS WEIGHT	ALT	OPERATING INSTRUCTIONS Rotor Speed	Approximate Tor/Eng	Approximate Fuel Flow	Speed/Knots	
Pounds	Feet	Rpm	Lb-Ft	Total lb/hr	TAS	IAS
40000 to 38001	8000	230	592	2212	83	68
	6000	230	557	2161	83	70
	4000	230	534	2157	83	73
	2000	230	520	2191	83	76
	SL	230	513	2250	82	77
38000 to 36001	10000	230	572	2112	83	65
	8000	230	536	2055	83	68
	6000	230	511	2039	83	70
	4000	230	497	2065	83	73
	2000	230	489	2115	82	75
	SL	230	485	2180	82	77
36000 to 34001	12000	230	550	2012	82	62
	10000	230	515	1950	83	65
	8000	230	489	1925	83	68
	6000	230	474	1943	83	70
	4000	230	465	1985	82	72
	2000	230	461	2046	81	74
	SL	230	459	2115	81	76
34000 to 32001	12000	230	491	1843	82	62
	10000	230	465	1813	82	65
	8000	230	451	1824	82	67
	6000	230	441	1861	82	70
	4000	230	437	1917	81	71
	2000	230	435	1980	81	73
	SL	230	434	2054	80	75

REMARKS:
1. No allowances have been made for fuel reserves.
2. This chart is suitable for operation at 225 rotor rpm.

DATA AS OF: August 1967
DATA BASIS: Flight Test

FUEL GRADE: JP-4
FUEL DENSITY: 6.5 Lb/Gal

HOVERING ENDURANCE

MODEL(S): CH-47B
ENGINE(S): (2) T55-L-7B

STANDARD DAY

CONFIGURATION: Clean

GROSS WEIGHT	ALT	OPERATING INSTRUCTIONS				
		Rotor Speed	Approximate Tor/Eng	Approximate Fuel Flow	Speed/Knots	
Pounds	Feet	Rpm	Lb-Ft	Total lb/hr	TAS	IAS
34000 to 32001	8000	230	744	2671	0	0
	6000	230	723	2636	0	0
	4000	230	705	2627	0	0
	2000	230	689	2636	0	0
	SL	230	674	2658	0	0
32000 to 28001	10000	230	700	2509	0	0
	8000	230	680	2471	0	0
	6000	230	663	2459	0	0
	4000	230	648	2466	0	0
	2000	230	634	2484	0	0
	SL	230	621	2518	0	0
28000 to 24001	14000	230	610	2179	0	0
	12000	230	592	2141	0	0
	10000	230	577	2127	0	0
	8000	230	563	2131	0	0
	6000	230	559	2145	0	0
	4000	230	540	2173	0	0
	2000	230	530	2216	0	0
	SL	230	522	2271	0	0
24000 to 20000	14000	230	488	1799	0	0
	12000	230	477	1802	0	0
	10000	230	466	1816	0	0
	8000	230	457	1840	0	0
	6000	230	449	1880	0	0
	4000	230	443	1932	0	0
	2000	230	441	1995	0	0
	SL	230	441	2070	0	0
40000 to 38001	SL	230	845	3137	0	0
38000 to 36001	2000	230	805	2968	0	0
	SL	230	786	2947	0	0
36000 to 34001	6000	230	786	2833	0	0
	4000	230	765	2801	0	0
	2000	230	746	2796	0	0
	SL	230	729	2808	0	0

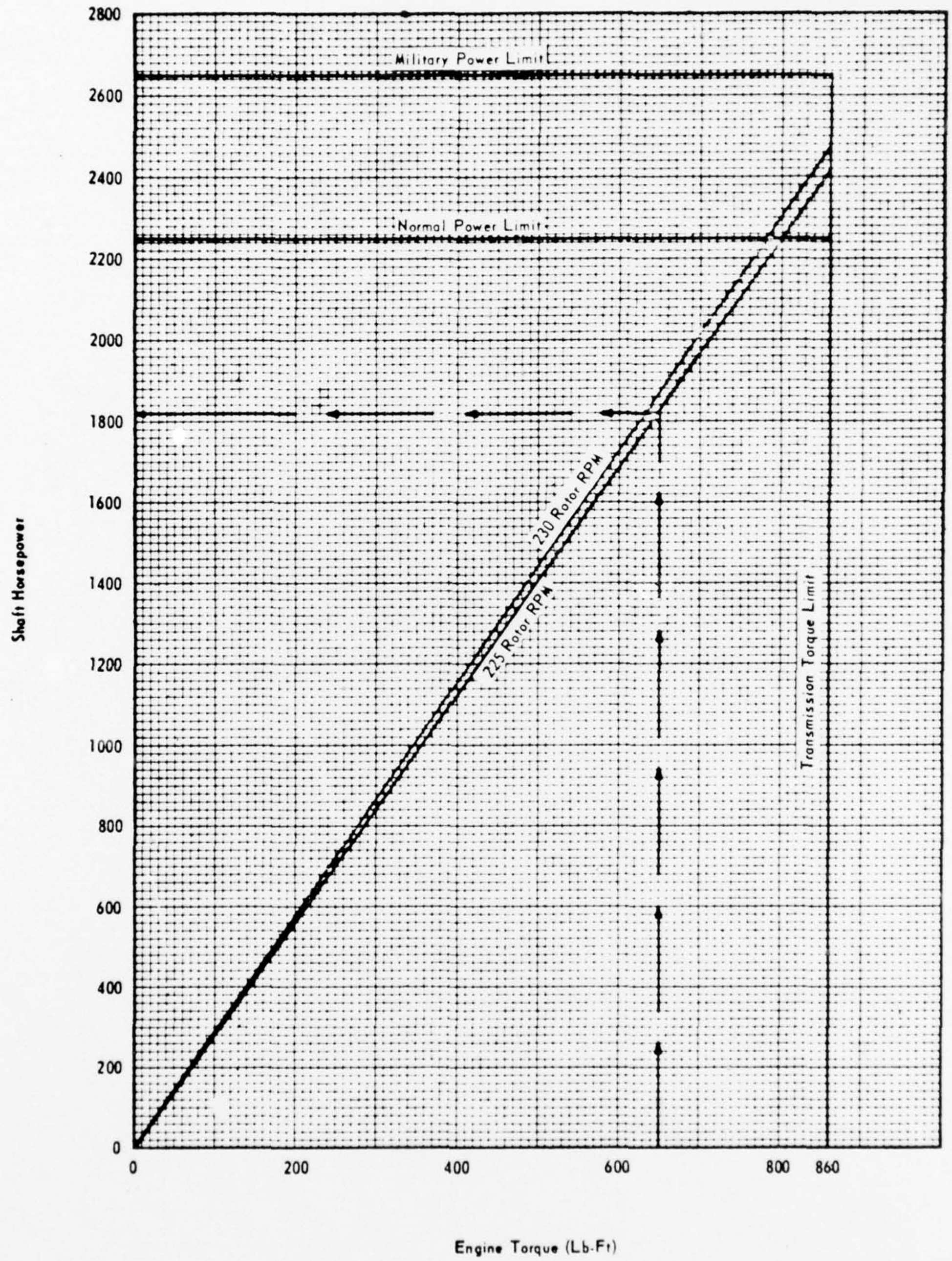
REMARKS: 1. No allowances have been made for fuel reserves.
2. This chart is suitable for operation at 225 rotor rpm.

DATA AS OF: August 1967
DATA BASIS: Flight Test

FUEL GRADE: JP-4
FUEL DENSITY: 6.5 Lb/Gal

Model: CH-47B
Data Basis: Calculated
Date: August 1967

Engines: T55-L-7B
Fuel Grade: JP-4
Fuel Density: 6.5 Lb/Gal



Power conversion chart

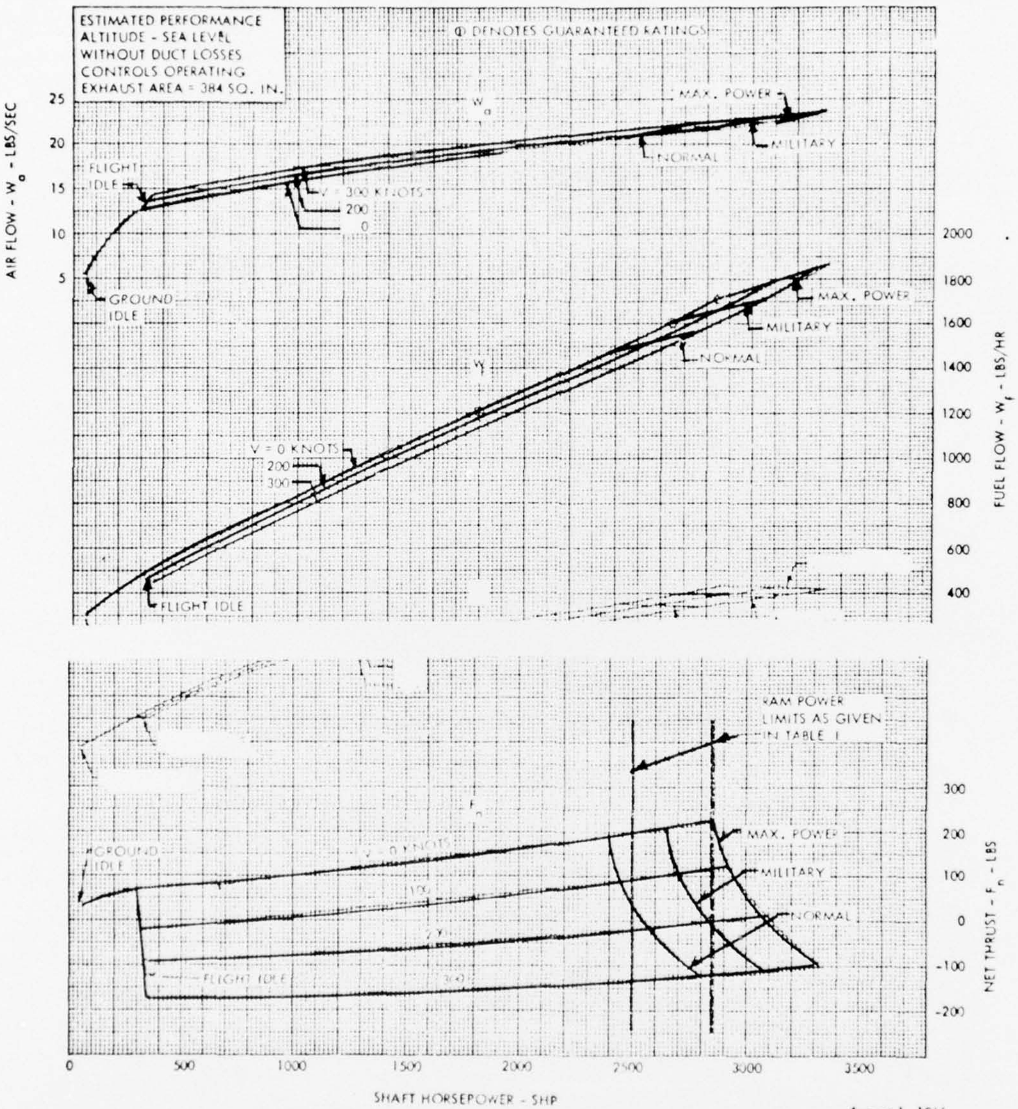
APPENDIX D (U)

SELECTED DATA FROM

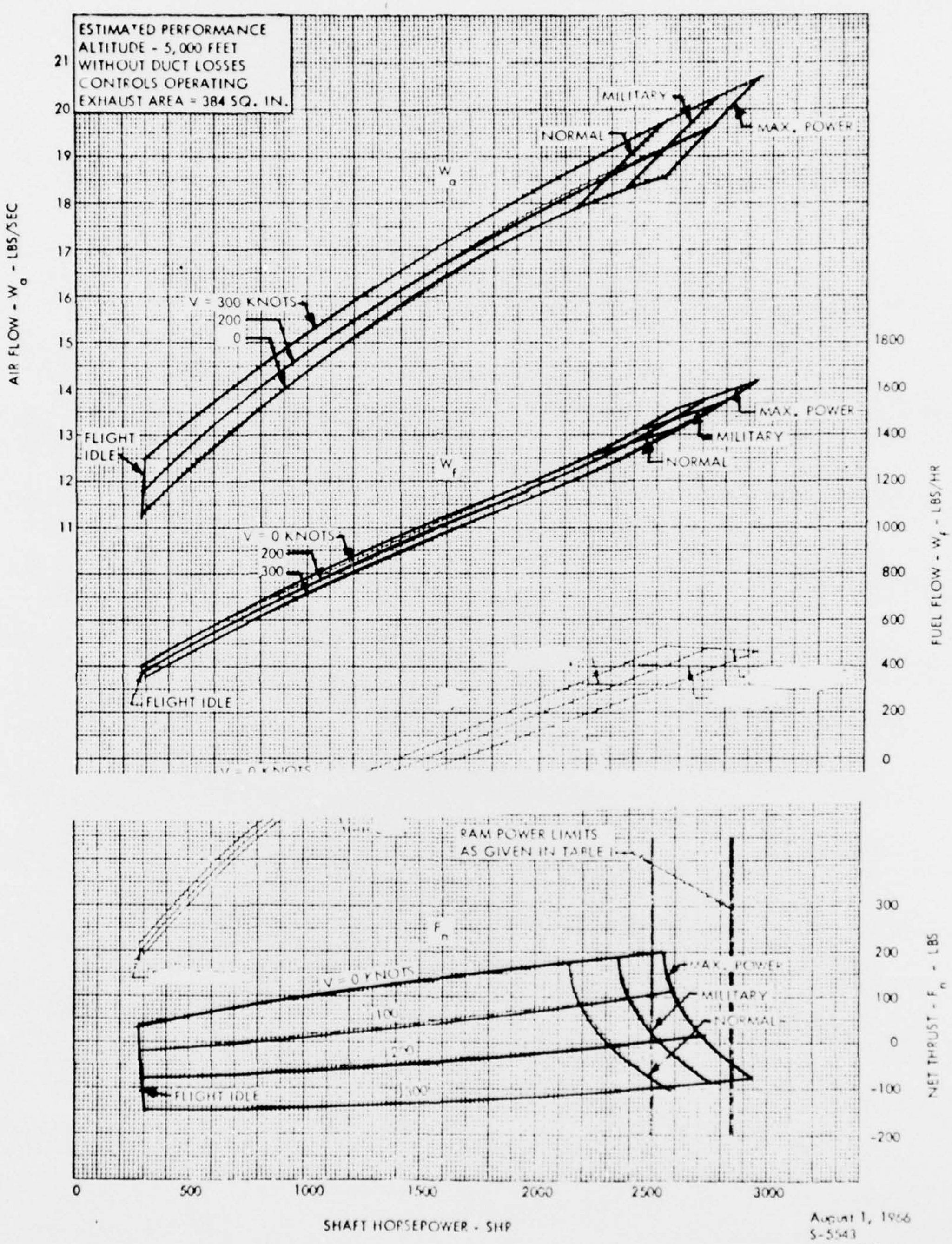
LYCOMING

ON THE

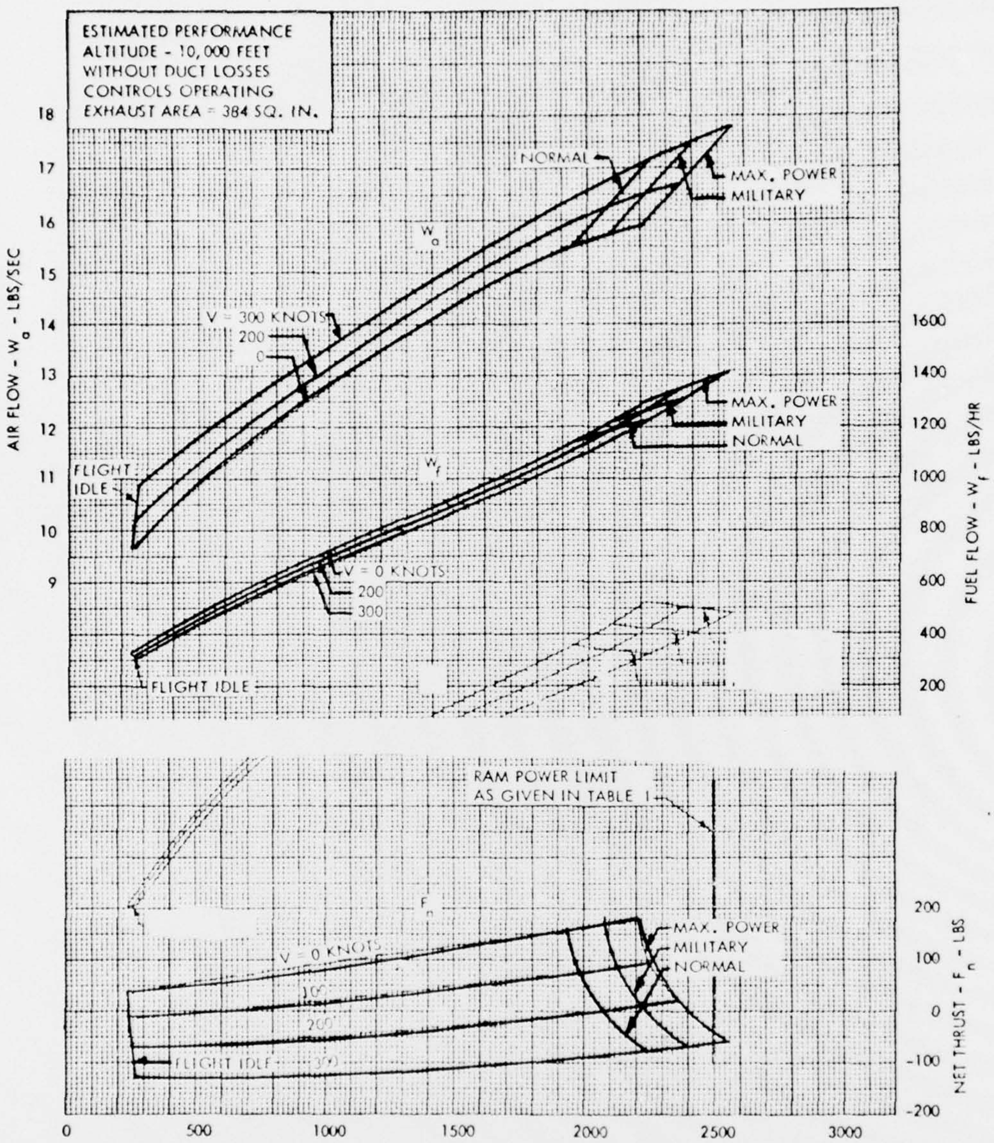
T55-L-7 TURBINE



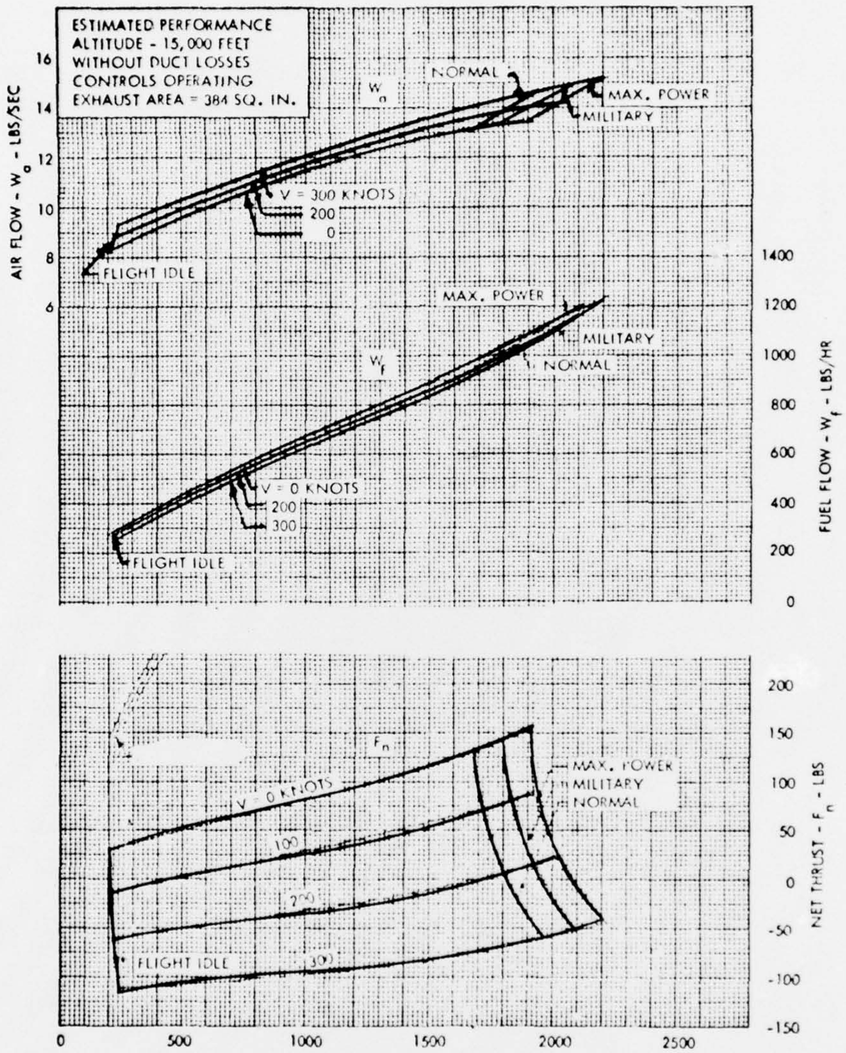
August 1, 1966
S-5542
Figure 1.1



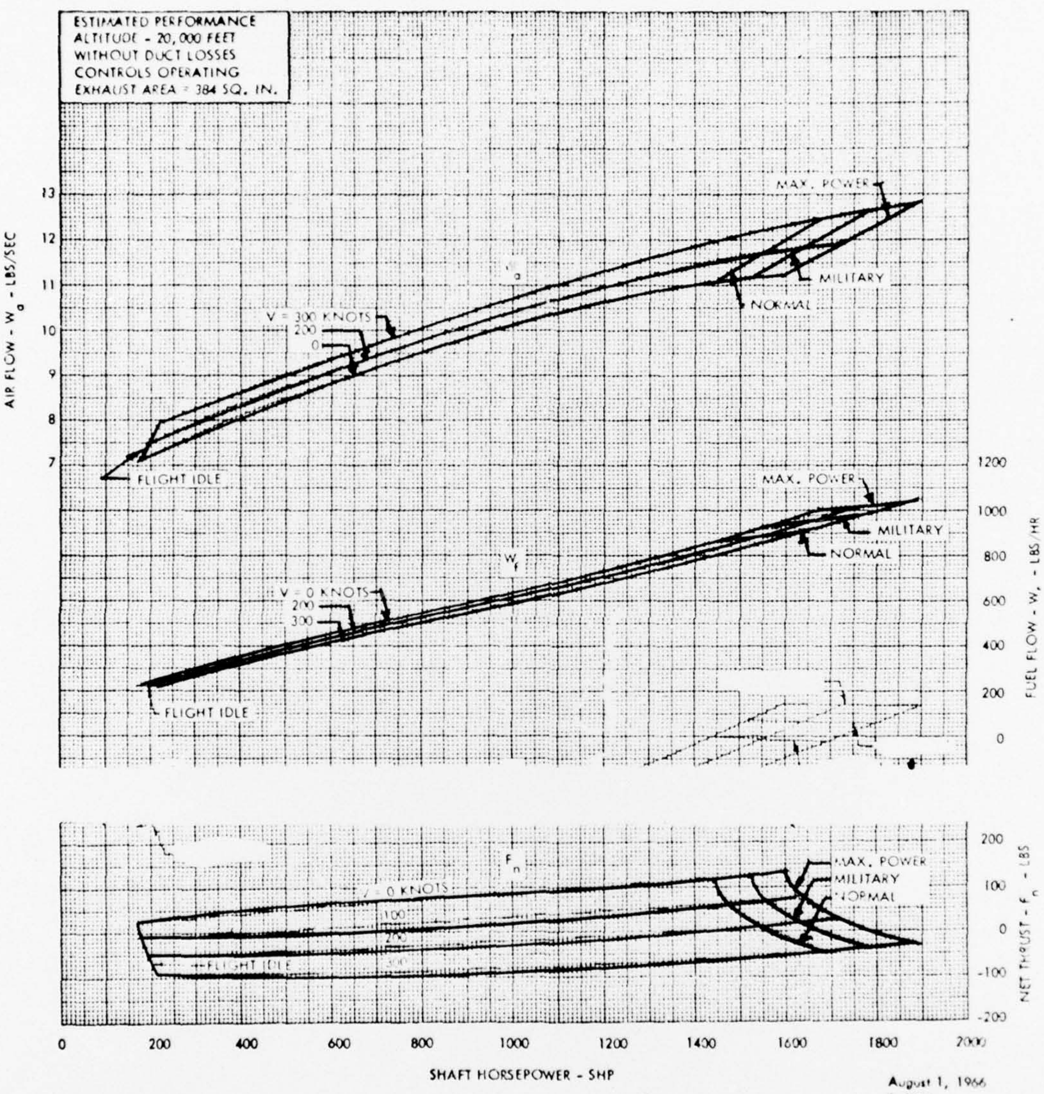
August 1, 1966
S-5543
Figure 1.2



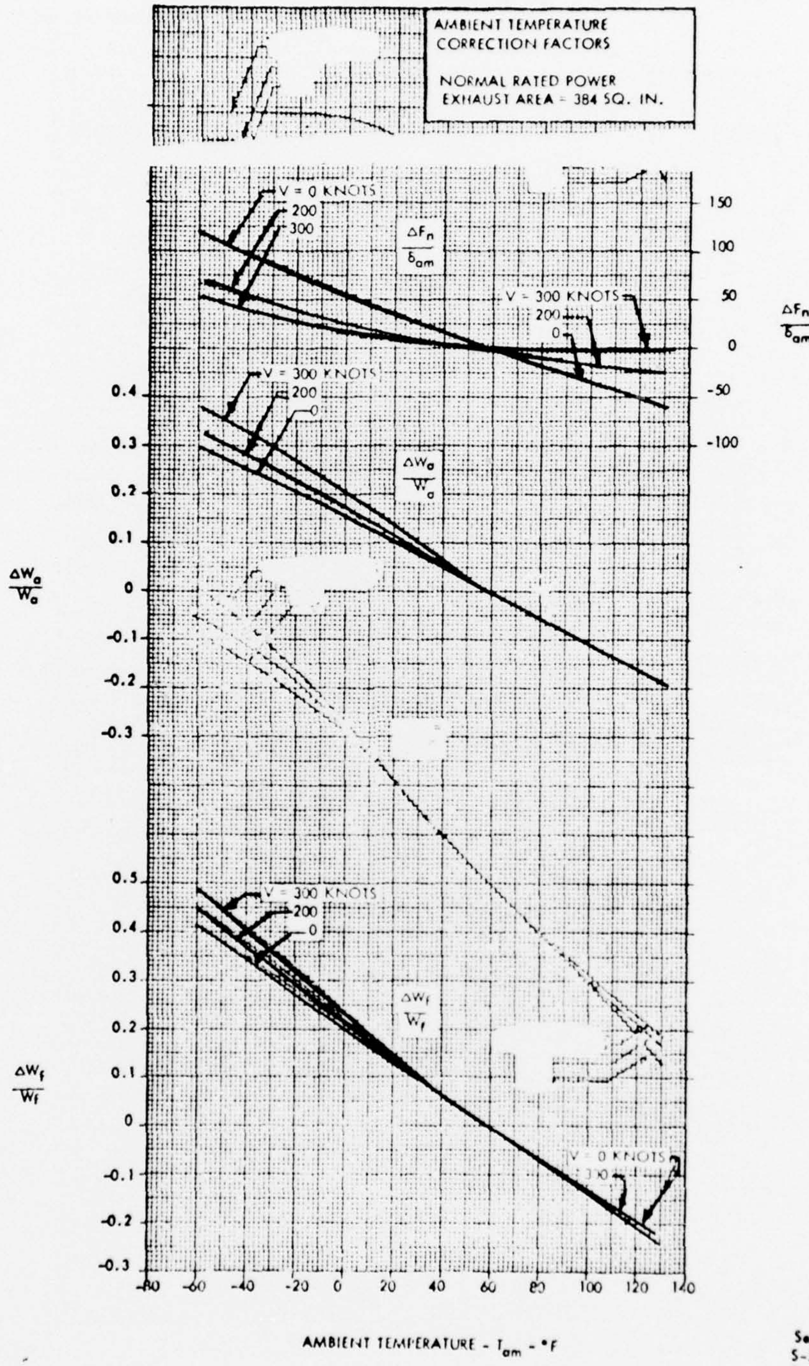
August 1, 1966
S-5544
Figure 1.3



August 1, 1966
S-5545
Figure 1.4



August 1, 1966
S-5546
Figure 1.5



Sept. 20, 1964
S-5339
Figure 2.3

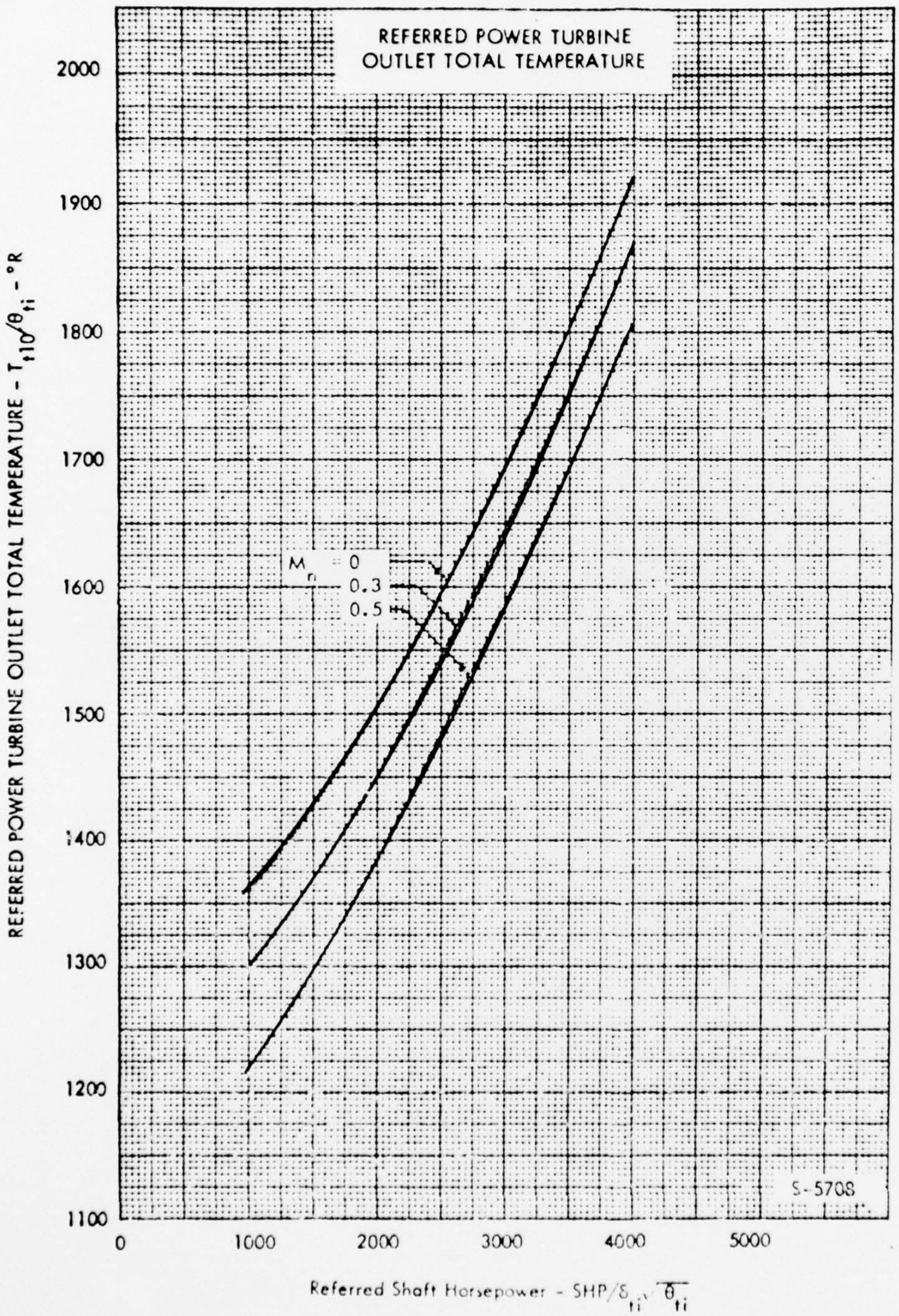


Figure 13
(Revised 30 September 1968)